by Tomas Hood, NW7US, pc-prop-man@hfradio.org

Reviewing Propagation And Space Weather Terms

On various Internet websites you will read—and during the hourly space weather and geophysical reports broadcast by the National Oceanic and Atmospheric Administration (NOAA) you will hear—terms and measurements that describe the various conditions and levels of solar activity and so on. For instance, NOAA uses the WWV and WWVH radio stations to issue geophysical alert messages that provide information about solar terrestrial conditions. Geophysical alerts are broadcast from WWV at 18 minutes after the hour and from WWVH at 45 minutes after the hour. You may also access these alerts on the Internet (see http://www.sec.noaa.gov/ftpdir/latest/wwv.txt) or by telephone. The messages are less than 45 seconds long and are updated every three hours (typically at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC). More frequent updates are made when necessary. WWV radiates 10,000 watts on 5, 10, and 15 MHz; and 2,500 watts on 2.5 and 20 MHz. WWVH radiates 10,000 watts on 5, 10, and 15 MHz, and 5,000 watts on 2.5 MHz. Each frequency is broadcast from a separate transmitter. Although each frequency carries the same information, multiple frequencies are used because the quality of HF reception depends on many factors, such as location, time of year, time of day, frequency being used, and atmospheric and ionospheric propagation conditions. The various frequencies make it likely that at least one frequency will be usable at all times. You can read the details about WWV and WWVH at http://www.boulder.nist.gov/timefreq/stations/wwv.html .

The geophysical alerts provide information about the current conditions for long-distance HF radio communications. The alerts use a standardized format and terminology that requires some explanation. Before looking at sample messages, let's look at some of that terminology.

Solar flux is a measurement of the intensity of 10.7-centimeter (roughly 2800-MHz) solar radio emissions. At 2000 UTC, the Dominion Radio Astrophysical Observatory of the Canadian National Research Council located at Penticton,

The Ap Index And Understanding Propagation Terminology

The Ap index, or Planetary A index, is a 24-hour averaging of the Planetary K index. The Planetary K index is an averaging of worldwide readings of Earth's geomagnetic field. High indices (Kp > 5 or Ap > 20) mean stormy conditions with an active geomagnetic field. The more active, the more unstable propagation is, with possible periods of total propagation fade-out. Especially around the higher latitudes and especially at the Polar Regions, where the geomagnetic field is weak, propagation may disappear completely. Extreme high indices may result in aurora propagation, with strongly degraded long distance propagation at all latitudes. Low indices result in relatively good propagation, especially noticeable around the higher latitudes, when transpolar paths may open up. Maximum K-index is 9, and the A-index can exceed well over 100 during very severe storm conditions, with no maximum.

Classification of A-indices is as follows:

A0–A7 = quiet	A30–A49 = minor storm
A8–A15 = unsettled	A50–A99 = major storm
A16–A29 = active	A100–A400 = severe storm

Solar Flux (SFI): This flux number is obtained from the amount of radiation on the 10.7-cm band (2800 MHz). It is closely related to the amount of ultraviolet radiation, which is needed to create the ionosphere. Solar Flux readings are more descriptive of daily conditions than the Sunspot Number. The higher the Solar Flux (and, therefore, the higher the Sunspot Number), the stronger the ionosphere becomes, supporting refraction of higher frequencies.

Ionosphere: A collection of ionized particles and electrons in the uppermost portion of the Earth's atmosphere, which is formed by the interaction of the solar wind with the very thin air particles that have escaped Earth's gravity. These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies, with these critical frequencies varying with the degree of ionization. As a result, radio waves having frequencies higher than the Lowest Usable Frequency (LUF) but lower than the Maximum Usable Frequency (MUF) are propagated over large distances.

Sunspot Number (SSN): Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Sunspots appear as dark spots on the surface of the Sun. Temperatures in the dark centers of sunspots drop to about 3700° K (compared to 5700° K for the surrounding photosphere). This difference in temperatures makes the spots appear darker than elsewhere. Sunspots typically last for several days, although very large ones may last for several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually occur in a group, with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the sunspots (called the "umbra"). The field is weaker and more horizontal in the lighter part (the "penumbra").

Galileo made the first European observations of sunspots in 1610. The Chinese and many other early civilizations have records of sunspots. Daily observations were started at the Zurich Observatory in 1749; continuous observations were begun in 1849.

The sunspot number is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The "sunspot number" is then given by the sum of the number of individual sunspots and 10 times the number of groups. Since most sunspot groups have, on average, about 10 spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see. Monthly averages (updated monthly) of the sunspot numbers show that the number of sunspots visible on the sun waxes and wanes with an approximate 11-year cycle.

For more information, see http://prop.hfradio.org.

Optimum Working Frequencies (MHz) - For February 2005 - Flux = 83, SSN = 24- Created by NW7US

UTC TO/FROM US WEST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	20	18	15	12	11	11	10	10	10	9	9	9	9	9	15	18	20	21	22	22	22	22	22	21
NORTHERN SOUTH AMERICA	28	26	23	17	16	15	14	14	13	13	12	12	12	12	17	23	25	27	28	29	30	30	29	29
CENTRAL SOUTH AMERICA	27	25	22	16	15	14	14	13	13	13	12	12	12	12	19	24	26	27	28	28	29	29	29	29
SOUTHERN SOUTH AMERICA	29	28	25	21	18	17	16	15	14	14	13	13	13	12	12	22	25	26	28	28	29	30	30	30
WESTERN EUROPE	9	9	9	8	8	8	8	8	8	8	8	8	8	8	11	14	15	16	15	15	13	10	10	9
EASTERN EUROPE	8	8	8	8	8	8	8	9	9	8	8	8	8	8	8	10	10	10	10	9	8	8	8	8
EASTERN NORTH AMERICA	22	20	17	13	12	12	11	11	11	10	10	10	10	10	17	20	22	23	24	24	24	24	24	23
CENTRAL NORTH AMERICA	13	12	11	9	7	7	6	6	6	6	6	6	6	5	5	10	11	12	13	13	13	13	13	13
WESTERN NORTH AMERICA	7	6	6	5	4	3	3	3	3	3	3	3	3	3	3	3	5	6	6	7	7	7	7	7
SOUTHERN NORTH AMERICA	21	20	18	14	12	11	11	10	10	10	9	9	9	9	9	17	19	21	22	22	23	23	23	22
NORTHERN AFRICA	9	9	9	9	8	8	8	9	9	8	8	8	8	8	12	15	16	17	17	16	11	10	10	10
CENTRAL AFRICA	11	11	11	10	10	9	9	9	9	8	8	8	8	8	12	14	16	17	17	15	14	13	12	12
SOUTH AFRICA	20	18	14	12	12	11	11	10	10	10	10	10	10	10	17	19	21	22	22	23	23	23	22	21
MIDDLE EAST	9	8	8	8	8	9	9	9	9	8	8	8	8	8	8	13	15	15	11	10	10	9	9	9
JAPAN	19	18	18	17	16	14	10	10	10	9	9	9	9	8	8	8	8	8	8	8	8	14	16	18
CENTRAL ASIA	19	18	18	17	16	14	10	10	10	9	9	9	9	8	8	8	8	11	11	10	10	10	14	19
INDIA	14	15	15	13	11	9	9	9	9	8	8	8	8	8	8	8	8	8	8	8	8	9	12	13
THAILAND	18	18	17	17	15	13	10	10	9	9	9	9	8	8	8	8	8	12	12	12	11	11	11	10
AUSTRALIA	24	25	27	27	25	21	16	15	14	14	13	13	12	12	12	12	12	16	15	14	15	18	20	22
CHINA	16	17	17	16	15	13	10	10	9	9	9	9	8	8	8	8	8	9	9	8	8	8	8	14

UTC TO/FROM US MIDWEST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
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NORTHERN SOUTH AMERICA	25	23	19	18	16	15	14	14	13	12	12	12	11	15	19	22	24	25	26	27	28	28	27	26
CENTRAL SOUTH AMERICA	26	23	19	18	17	16	15	14	14	13	13	12	12	20	23	24	26	27	28	29	29	29	29	28
SOUTHERN SOUTH AMERICA	28	26	23	21	19	18	16	16	15	14	14	13	13	14	21	24	25	27	28	29	29	30	30	30
WESTERN EUROPE	9	9	9	8	8	8	8	8	8	8	8	8	8	14	16	17	17	17	16	16	14	12	10	9
EASTERN EUROPE	8	8	8	8	8	8	8	8	8	8	8	8	8	12	14	14	13	13	12	12	10	9	9	9
EASTERN NORTH AMERICA	15	13	10	9	9	8	8	8	8	7	7	7	7	11	14	16	17	17	18	18	18	18	17	16
CENTRAL NORTH AMERICA	7	7	6	4	4	4	4	3	3	3	3	3	3	3	5	7	7	8	8	8	8	8	8	8
WESTERN NORTH AMERICA	13	12	11	9	7	7	6	6	6	6	6	6	6	6	5	10	11	12	13	13	14	14	14	13
SOUTHERN NORTH AMERICA	15	13	11	9	8	8	7	7	7	7	7	7	6	6	11	13	15	15	16	16	16	16	16	15
NORTHERN AFRICA	11	11	10	10	9	9	9	9	8	8	8	8	10	15	17	18	18	19	19	19	16	13	12	12
CENTRAL AFRICA	12	11	10	10	9	9	9	9	8	8	8	8	10	15	17	18	18	19	19	17	15	14	13	13
SOUTH AFRICA	20	16	15	14	14	13	13	13	12	12	12	12	16	23	26	27	29	29	29	29	29	27	24	22
MIDDLE EAST	9	9	8	8	8	8	9	9	8	8	8	8	8	14	16	17	18	16	13	11	10	10	9	9
JAPAN	18	17	16	14	10	10	10	9	9	9	9	8	8	8	8	9	9	8	8	8	8	13	16	17
CENTRAL ASIA	18	17	16	14	10	10	9	9	9	9	9	8	8	8	8	10	11	11	11	10	10	10	11	18
INDIA	11	13	12	10	9	9	9	9	8	8	8	8	8	8	12	14	13	12	9	9	9	9	8	8
THAILAND	17	16	15	13	10	10	9	9	9	9	8	8	8	8	8	12	13	12	12	11	11	11	11	10
AUSTRALIA	24	26	26	23	17	15	14	14	13	13	13	12	12	12	12	14	17	16	15	14	16	19	21	23
CHINA	15	16	15	13	10	10	9	9	9	9	8	8	8	8	8	9	9	9	9	8	8	8	8	12
SOUTH PACIFIC	28	28	26	23	19	17	16	15	15	14	13	13	13	12	12	17	16	15	17	20	22	24	26	27

UTC TO/FROM US EAST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	17	15	13	12	12	11	10	10	9	9	9	9	11	15	18	19	20	21	21	21	21	21	20	19
NORTHERN SOUTH AMERICA	22	21	19	17	16	15	14	13	12	12	11	11	12	16	19	21	22	23	24	25	25	25	24	24
CENTRAL SOUTH AMERICA	26	23	21	19	18	17	16	15	14	14	13	13	19	21	23	25	26	27	28	28	29	29	29	28
SOUTHERN SOUTH AMERICA	28	25	23	21	20	18	17	16	15	14	14	13	16	20	22	24	26	27	28	29	29	30	30	29
WESTERN EUROPE	9	9	8	8	8	8	8	8	8	8	8	12	15	16	17	17	17	17	17	16	15	12	10	9
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EASTERN NORTH AMERICA	7	5	4	4	4	4	4	3	3	3	3	3	4	7	8	8	8	9	9	9	9	8	8	8
CENTRAL NORTH AMERICA	16	14	10	10	9	9	8	8	8	8	8	8	8	12	15	17	18	18	19	19	19	19	18	17
WESTERN NORTH AMERICA	22	20	17	13	12	12	11	11	11	10	10	10	10	10	17	20	22	23	24	24	25	24	24	23
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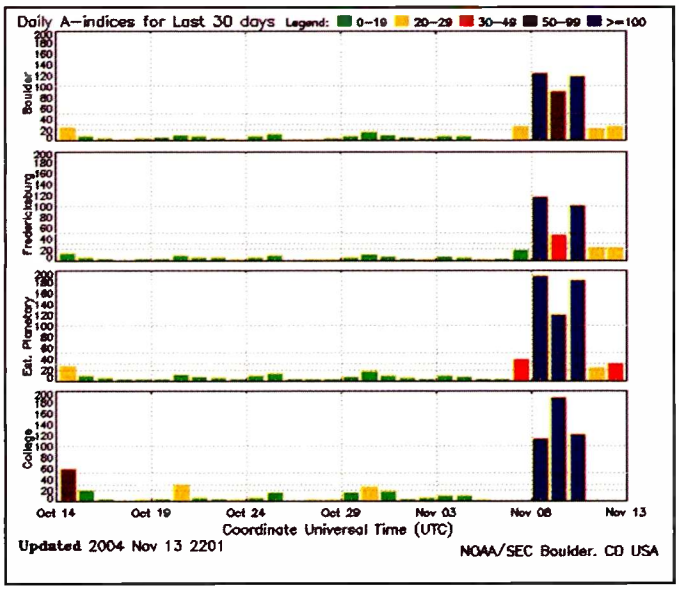
CENTRAL AFRICA	13	12	12	11	11	11	10	10	10	10	10	17	21	22	24	24	25	24	22	19	17	15	14	13
SOUTH AFRICA	19	18	17	16	15	14	14	13	13	13	12	19	24	27	28	29	29	29	29	29	29	27	24	22
MIDDLE EAST	11	10	10	9	9	9	9	8	8	8	8	13	16	18	19	19	20	20	18	13	13	12	12	11
JAPAN	16	14	10	10	10	9	9	9	9	8	8	8	8	9	9	9	9	8	8	8	8	12	15	17
CENTRAL ASIA	15	13	10	10	9	9	9	9	8	8	8	8	8	12	12	11	11	11	11	10	10	10	10	17
INDIA	8	8	8	8	8	8	9	8	8	8	8	8	12	15	15	15	14	13	12	10	9	9	9	9
THAILAND	13	10	10	9	9	9	9	9	8	8	8	8	10	14	15	14	13	12	12	11	11	11	11	10
AUSTRALIA	25	25	21	16	15	15	14	13	13	13	12	12	12	12	19	18	17	16	15	14	16	19	21	23
CHINA	14	11	10	10	9	9	9	9	8	8	8	8	8	10	10	9	9	9	9	8	8	8	8	8
SOUTH PACIFIC	28	26	22	20	18	17	16	15	14	14	13	13	13	13	18	16	15	15	19	22	24	26	27	28



The Kp levels during the storm of November 7 to November 10, 2004. The geomagnetic activity reached extreme storm levels of 9. (NOAA)

British Columbia, Canada, records the daily solar flux measurement. The solar flux index broadcast ranges from a theoretical minimum of about 50 to numbers larger than 300. During the early part of each 11-year sunspot cycle, the flux numbers are low, but they rise and fall as the cycle proceeds. The numbers will remain high for extended periods around sunspot maximum. (See the sidebar for more details.)

The *K indices* are a measurement of the behavior of the magnetic field in and around the Earth. The K index uses a scale from 0 to 9 to measure the change in the horizontal component of the geomagnetic field. A new K index is determined every three hours based on magnetometers around the world. Usually, the reported K index is the *planetary K index (Kp)*, which is an average of all the many K index readings from around the globe.

The *planetary A index (Ap)* is a daily value measured on a scale from 0 to 400 to express the range of disturbance of the geomagnetic field. It's obtained by converting and averaging the eight, 3-hour K index values. An estimate of the A index is first announced at 2100 UTC, based on seven measurements and one estimated value. At 0000 UTC, the announced A index consists entirely of known measurements, and the word "estimated" is dropped from the announcement.

Space weather describes the conditions in space that affect earth and its technological systems. Space weather is a consequence of the behavior of the sun, the nature of earth's magnetic field and atmosphere, and our location in the solar system.

Space weather storms observed and expected are characterized using the NOAA Space Weather Scales. The abbreviated table in **Table 1** shows the levels of activity that are included in the announcements and the associated terminology. The descriptor used to identify observed or expected conditions is the maximum level reached or predicted. The NOAA Space Weather Scales are further described on the Space Environment Center's website at http://www.sec.noaa.gov/NOAAscales.

Geomagnetic storm levels are determined by the estimated three-hourly Kp indices derived in real time from a network of Western Hemisphere ground-based magnetometers. These levels are shown in **Table 2**. When the K index reaches 6 and above, there is a very good chance that Au conditions exist. When the K index reaches 5 or higher, you might wish to check Au conditions at http://www.sec.noaa.gov/pmap/.

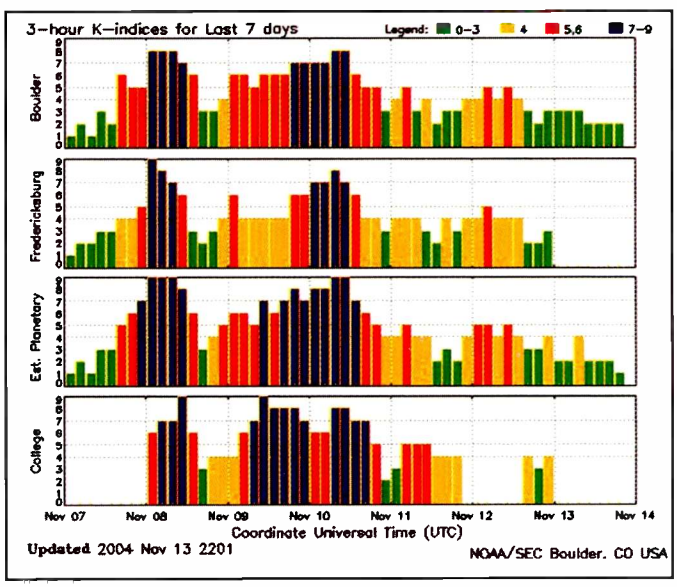
Table 1. NOAA Space Weather Scales

Geomagnetic Storms	Solar Radiation Storms	Radio Blackouts	Descriptor
G5	S5	R5	Extreme
G4	S4	R4	Severe
G3	S3	R3	Strong
G2	S2	R2	Moderate
G1	S1	R1	Minor

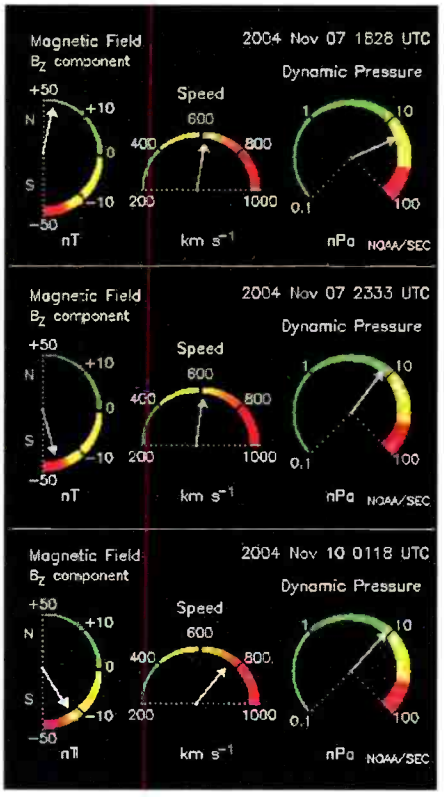
Solar radiation storm levels are determined by the proton flux measurements made by NOAA's primary Geostationary Operational Environmental Satellite (GOES). **Table 3** details these levels.

Radio Blackout levels are determined by the x-ray level measured by the primary GOES satellite. X-ray radiation ionizes the *D* layer causing absorption of HF signals, starting at the lower frequencies and increasing up to higher HF frequencies with higher levels of radiation. X-ray levels and related flares are categorized using the letters B, C, M, and X, with X being the most intense. **Table 4** correlates x-ray levels and flux to radio blackout levels.

Every geophysical alert consists of three parts. The first part contains the solar-terrestrial indices for the day, specifically the solar flux, the A index, and the K index. The next part is the space weather storms observed during the previous 24 hours. This includes all observed geomagnetic storms, solar radiation storms (proton events), and radio blackouts (class M1 and greater flares). Finally, the third part gives the space



The Ap levels during the storm of November 7 through November 10, 2004. The Ap index reached as high as 189, indicating a pretty strong geomagnetic storm level. The geomagnetic storm lasted for several days and virtually wiped out communications on medium and high frequencies. (NOAA)



The top instance of the Real-Time Solar Wind Scales provided by NOAA shows the strong solar wind speed at the beginning of the storm of November 7, 2004. As the storm started, the Interplanetary Magnetic Field (IMF) was oriented opposite of the Earth's geomagnetic field, so the increase in solar wind speed and density barely effected the Kp readings. However, when the IMF reversed, as shown by the Bz component turning negative in the next two instances shown, the geomagnetic field became very stormy, as recorded by the Kp indices which reached the maximum level of 9. (NOAA)

weather expected during the following 24 hours. An example geophysical alert is as follows:

"Solar-terrestrial indices for 08 February follow. Solar flux 89 and Mid-Latitude A-index 26. The Mid-latitude K-index at 1500 UTC on 08 February was 4. Space weather for the past 24 hours has been moderate. Solar radiation storm(s) reaching the S4 level is in progress. Radio blackouts(s) reaching the R2 level occurred."

Here's another example:

"Solar-terrestrial indices for 08 February follow. Solar flux 109 and Mid-Latitude A-index 17. The Mid-latitude K-index at 1500 UTC on 08 February was 3. No Space weather storms have been observed during the past 24 hours. Space weather for the next 24 hours is expected to be severe. Solar radiation storms reaching the S4 level are expected to continue. Radio blackouts reaching the R2 level are expected."

To hear the current geophysical alert message, tune to one of the frequencies of WWV or WWVH at the times provided above. My eAlert e-mails contain these reports, plus other related information. If you wish to sign up for my eAlerts, visit http://propagation.hfradio.org/ealert/.

Current Cycle 23 Progress

The Sun has proved again that solar activity can flare up unexpectedly at any time during the decline of the 11-year solar cycle. A great example is the flare-up during November 2004. A weeklong series of coronal mass ejection (CME) shock waves barraged the Earth during the week of November 7. The passage of many solar plasma clouds, the result of moderate to strong solar flares just days before, caused severe geomagnetic storms that wiped out virtually all HF and MW communications, though it did provide great Au mode propagation on VHF and above. Kp index readings reached 9 at times (the highest index mark). The resulting planetary A index (Ap) reached 189 on November 8, 120 on November 9, and back up to 181 on November 10, 2004.

Table 2. Geomagnetic Storm Levels

Kp Indices	Geomagnetic Storm Level
K = 5	G1
K = 6	G2
K = 7	G3
K = 8	G4
K = 9	G5

Best Scanner Antenna
Best obstruction-penetrating in user surveys and testimonials.
NILJON ANTENNAS
Grove Enterprises 800-438-8155
www.grove-ent.com
Universal Radio 800-431-3939
www.universal-radio.com

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Keep your HT and it's accessories in one place and protected In this tough, padded case. Big enough for your radio, extra antenna, battery and charger along with your repeater book. Zippered case comes in two sizes to fit any HT
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The "Receive Console" 8.5"W x 6.2"D x 3.3"H
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- Monitor Up to 6 Radios
- Only 2 Speakers Required
- Two Audio Field Configurations to Choose From
- Multiple Mute Functions
- Man. & VOX Recorder Control
- Busy Light for each Radio
- Stereo Amp Provides Plenty of Audio

NCS-3203 Multi-Rx II
NEW!

The "Mini-Receive Console" 8.5"W x 6.2"D x 2.0"H
$239.95 Introductory Price
- Monitor Up to 4 Radios
- Automatically Provides Selected & Unselected Audio to Separate Speakers
- Separate Volume Controls for Selected & Unselected Audio
- Selectively Mute Unselected Radios
- Stereo Amplifier Provides Up to 4 Watts/Ch

The Multi-Rx and Multi-Rx II provide a single point of control for simultaneously monitoring multiple radios. Great additions to the Listening Post or Ham Shack ! Get Yours TODAY !
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www.ncsradio.com

Table 3. Solar Radiation Storm Levels

Flux Level of >10 MeV Particles	Solar Radiation Storm Level
10	S1
10^2	S2
10^3	S3
10^4	S4
10^5	S5

Table 4. Radio Blackouts (Caused by X-ray Flares)

Peak Flare X-ray Level	X-ray Flux Level	Radio Blackout Level
M1	10^{-5}	R1
M5	5×10^{-5}	R2
X1	10^{-4}	R3
X10	10^{-3}	R4
X20	2×10^{-3}	R5

The Royal Observatory of Belgium reports that the monthly mean observed sunspot number for October 2004 was 48, up from September's 28 and August's 41. The lowest daily sunspot value during October was recorded on October 10, with a count of zero. The highest daily sunspot count was 99 on October 24. The 12-month running smoothed sunspot number centered on April 2004 was 46, a point under March's. A smoothed sunspot count of 22 is expected for February 2005, give or take about 12 points.

The Dominion Radio Astrophysical Observatory reports a 10.7-centimeter observed monthly mean solar flux of 106 for October 2004, up three points from September. The 12-month smoothed 10.7-centimeter flux centered on April 2004 is 112, down from March's 115. The predicted smoothed 10.7-centimeter solar flux for January 2005 is about 83, give or take about 16 points.

The observed monthly mean Ap index for October 2004 was 9, down a point from September. The 12-month smoothed Ap index centered on April 2004 is 16, about one point down from March. Expect the overall geomagnetic activity to be quiet to active during most days in February, though there is a possibility of a strong geomagnetic storm.

HF Propagation

We're starting to approach the end of the winter season. The period of darkness is growing shorter, causing the average daily maximum usable frequencies (MUFs) to rise a bit. At the same time, noise levels are still low, making for reliable DX. The solar activity is moderate, and holds enough energy to keep the mid-HF spectrum alive with signals. General conditions are expected to be good to excellent for HF propagation throughout February.

Nineteen meters through 15 meters will open shortly after sunrise and will remain open until early to late evening. Morning and evening DX openings between some areas in the Northern Hemisphere on these bands are very short, because the band in question closes on one end of the path before it opens on the opposite end. Transequatorial propagation on these bands will be more likely toward sunset during days of high solar flux and a disturbed geomagnetic field (look for days with an Ap greater than 15, or a Kp greater than 3).

Paths on 31 through 22 meters remain in their seasonal peak much like in January, but with longer openings. Continue to look for great openings between North America and Europe in the morning and between North America and Asia during the late afternoon hours. Twenty-two meters will often be the best daytime DX band, with 31 and 25 running a close second.

Ninety through 41 meters will be useful almost 24 hours a day. Daytime conditions will resemble those of 25 meters, but skip and signal strength may decrease during midday on days with high solar flux values. Nighttime will be good except after days of very high MUF conditions. Generally, the usable distance is expected to be somewhat greater on the higher of these bands than on 90. DX activity tends to increase later in the evening toward midnight. Look for Africa and the South Pacific (Australia, Papua New Guinea, and so on) on 90 through 60 meters throughout the night. On 41, 49, and 60 meters, long-path DX is possible along the gray line.

The 120-meter band continues to remain stable, with very low noise levels. Throughout the winter season, high noise may occur during regional snowstorms. The band opens just before sunset and lasts until the sun comes up on the path of interest. Except for daytime short-skip signal strengths, high solar activity has little impact. Continue to look for Europe and Africa around sunset until the middle of the night, and then Asia, the Pacific, and the South Pacific as morning approaches.

Signals below 120 meters will remain strong and exciting, except during times of regional storms and high geomagnetic activity. Mediumwave DX is still quite hot throughout February.

VHF And Above

There are no major meteor showers during February that could provide any VHF meteor scatter propagation. But other modes may be possible. Check for 6-meter short-skip openings during the daylight hours. Some short-skip openings over distances of about 1,200 to 2,300 miles may occur. The best times for these are during the afternoon hours.

Au activity often occurs during periods of radio storminess on the HF bands. Look for days where the planetary Ap index is climbing and when the Kp index reaches 4 or higher. These are the days on which VHF Au-type openings are most likely to occur.

I'd Like To Hear From You

You can join in with others in discussing space weather, propagation, and shortwave or VHF listening at http://hfradio.org/forums/. Be sure to check out the latest conditions, as well as the educational resources about propagation, which I have put together for you at http://prop.hfradio.org/. I also provide a WAP/WML resource for wireless devices. If you want the latest propagation information like the solar flux, Ap reading, and so forth, check out http://wap.hfradio.org/, the wireless version of my propagation site.

Please don't hesitate to write and let me know about any interesting propagation you've noticed. Do you have questions about propagation? I look forward to hearing from you. Turn on your favorite radio and enjoy the great DX season on the medium and shortwaves. Happy hunting!

by Tomas Hood, NW7US, pc-prop-man@hfradio.org

Reviewing Propagation And Space Weather Terms—Part II Coronal Holes And Coronal Mass Ejections

The atmosphere above the Sun's surface is divided into layers, much like Earth's atmosphere is divided into a troposphere and so on. The Sun's layers are the *corona* and, below that, the *chromosphere,* and the *photosphere*, the latter being where sunspots occur. Using an instrument called a *coronagraph* we can see the corona and the features that occur in that layer. The coronagraph is effectively a man-made eclipse and is used both in space aboard space vehicles (satellites and space stations) and at high-altitude solar observatories on the Earth. The devices allow us to see the pearly white crown of the corona surrounding the Sun whenever we want.

Using a coronagraph, we have discovered various features of the Sun's corona. *Coronal holes* an d *coronal mass ejections* (*CMEs*) are two such features, both of which can have a significant impact on space weather and radio propagation. These were discovered when x-ray telescopes were first flown above the Earth's atmosphere to reveal the structure of the corona across the solar disc.

Coronal holes are regions where the corona is dark. It is not a real "hole," as in a dip in some surface. Remember, the corona is not part of the Sun's surface, but instead part of its atmosphere (again, like our troposphere, stratosphere, and so on). Coronal holes are associated with "open" magnetic field lines and are often found at the Sun's poles.

A CME, sometimes also known as a centimetere, is created by one of several complex and dramatic events. When a bubble of plasma inside a coronal hole bursts, a huge cloud of that plasma spews outward away from the Sun. The bursting of the bubble is caused by the magnetic breakdown of the coronal hole. Another cause of CMEs is major impulsive solar flares punching through the corona, if the geometry and velocity of the flare-ejected material is sufficient to allow the gas to escape the solar

The Ap Index And Understanding Propagation Terminology

The Ap index, or Planetary A index, is a 24-hour averaging of the Planetary K index. The Planetary K index is an averaging of world-wide readings of Earth's geomagnetic field. High indices (Kp > 5 or Ap > 20) mean stormy conditions with an active geomagnetic field. The more active, the more unstable propagation is, with possible periods of total propagation fade-out. Especially around the higher latitudes and especially at the Polar Regions, where the geomagnetic field is weak, propagation may disappear completely. Extreme high indices may result in aurora propagation, with strongly degraded long distance propagation at all latitudes. Low indices result in relatively good propagation, especially noticeable around the higher latitudes, when trans-polar paths may open up. Maximum K-index is 9, and the A-index can exceed well over 100 during very severe storm conditions, with no maximum.

Classification of A-indices is as follows:

A0–A7 = quiet	A30–A49 = minor storm
A8–A15 = unsettled	A50–A99 = major storm
A16–A29 = active	A100–A400 = severe storm

Solar Flux (SFI): This flux number is obtained from the amount of radiation on the 10.7-cm band (2800 MHz). It is closely related to the amount of ultraviolet radiation, which is needed to create the ionosphere. Solar Flux readings are more descriptive of daily conditions than the Sunspot Number. The higher the Solar Flux (and, therefore, the higher the Sunspot Number), the stronger the ionosphere becomes, supporting refraction of higher frequencies.

Ionosphere: A collection of ionized particles and electrons in the uppermost portion of the Earth's atmosphere, which is formed by the interaction of the solar wind with the very thin air particles that have escaped Earth's gravity. These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies, with these critical frequencies varying with the degree of ionization. As a result, radio waves having frequencies higher than the Lowest Usable Frequency (LUF) but lower than the Maximum Usable Frequency (MUF) are propagated over large distances.

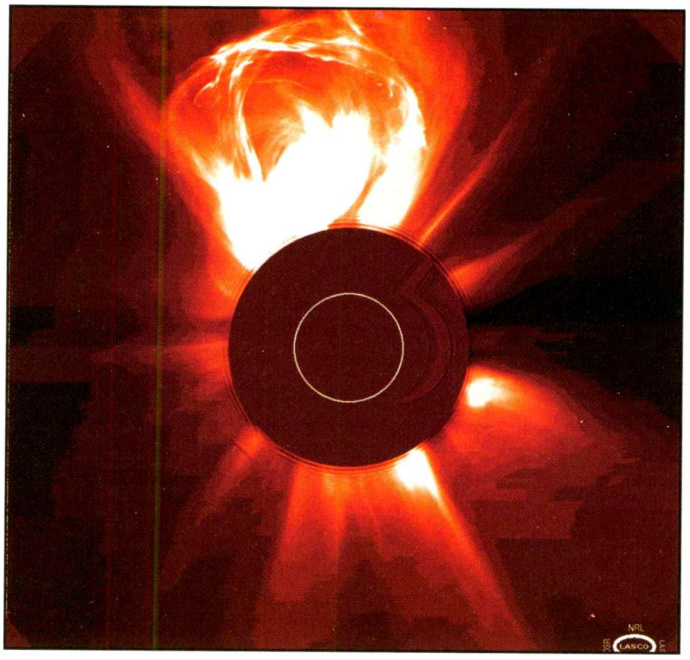
Sunspot Number (SSN): Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Sunspots appear as dark spots on the surface of the Sun. Temperatures in the dark centers of sunspots drop to about 3700° K (compared to 5700° K for the surrounding photosphere). This difference in temperatures makes the spots appear darker than elsewhere. Sunspots typically last for several days, although very large ones may last for several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually occur in a group, with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the sunspots (called the "umbra"). The field is weaker and more horizontal in the lighter part (the "penumbra").

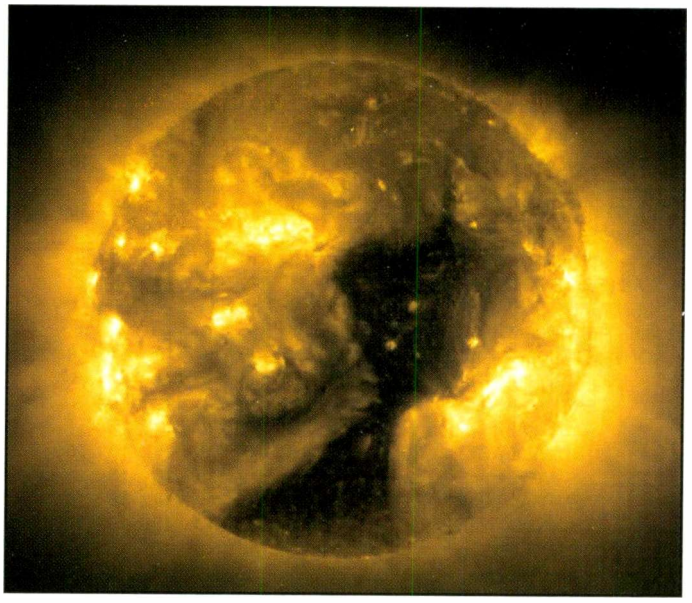
Galileo made the first European observations of sunspots in 1610. The Chinese and many other early civilizations have records of sunspots. Daily observations were started at the Zurich Observatory in 1749; continuous observations were begun in 1849.

The sunspot number is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The "sunspot number" is then given by the sum of the number of individual sunspots and 10 times the number of groups. Since most sunspot groups have, on average, about 10 spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see. Monthly averages (updated monthly) of the sunspot numbers show that the number of sunspots visible on the sun waxes and wanes with an approximate 11-year cycle.

For more information, see http://prop.hfradio.org.



This x-ray image of the sun, captured on February 21, 2000 by the Japanese Yohkoh X-ray Observatory shows a coronal hole (the dark area) that has rotated into a favorable position to send high-speed solar wind particles toward Earth. The resulting gusts of solar wind strike Earth's magnetic field and trigger moderate geomagnetic disturbances. (Source: NASA)



On March 9, 2000, a coronal mass ejection, also known as a centimetere, erupted off the active solar surface and blasted this enormous bubble of magnetic plasma into space. Direct light from the Sun is blocked in this picture of the event, with the sun's relative position and size indicated by a white half-circle at bottom center. The field of view extends 2 million kilometers or more from the solar surface. While hints of these explosive events were discovered by spacecraft in the early 1970s, this dramatic image is part of a detailed record of this CME's development from the SOHO spacecraft. Near the minimum of the solar activity cycle, CMEs occur about once a week. (Source: SOHO Consortium, ESA, NASA)

gravitational field. However, a somewhat larger number of CMEs are associated with other phenomena than those produced by solar flares.

CMEs can occur at any time during the solar cycle, but their occurrence rate increases with increasing solar activity and peaks around solar maximum. Since the Sun completes a full rotation every 27 to 28 days, the same CME may recur every month. The exact processes involved in the release of CMEs are not known, but we do know a lot about how they affect the Earth. The result of a well-placed CME is a bombardment of plasma into our magnetosphere (the magnetic force field that in part protects us from lethal doses of solar energy), as well as an increase in the density, power level, and speed of the solar wind.

When the solar wind, which contains magnetic field lines, reaches the magnetosphere, one of two things may happen. If the magnetic lines in the solar wind are orientated just right, or in a southerly orientation, they will combine in a way that nullifies the magnetosphere at that point, causing a "window" to open, allowing solar plasma to enter into our atmosphere. If the magnetic lines in the solar wind are not orientated this way, they will combine with the magnetosphere in a way that enhances the magnetosphere, strengthening the force field. When plasma does makes it through, the geomagnetic fields as well as the ionosphere become highly disturbed, and you will see higher planetary A-Index (Ap) and planetary K-Index (Kp) readings. When the plasma and radiation is blocked, we have more quiet geomagnetic conditions with Kp readings less than 4.

Grayline Propagation

During the daylight hours, the energy from the Sun ionizes our upper atmosphere, causing distinct layers of ionized gas to form. These layers constitute what we call the *ionosphere*. The layer closest to the Earth is called the *D layer*. It generally absorbs some of the energy of a radiowave, hence the *D* layer is often called the *absorption layer*. Higher up in our ionosphere we find the *E layer*, which plays a role in *sporadic-E* (*Es*) propagation, as well as some absorption. Higher yet, we find the *F layer*. The *E* and *F* layers refract radio signals back to Earth if the signal's frequency is at or below the *Maximum Usable Frequency* (*MUF*). During the day, the Sun is ionizing these *D*, *E*, and *F* layers.

As a radio signal travels through the *D* layer, it gets attenuated. How much attenuation depends on how ionized the *D* layer has become. During solar flares, x-ray radiation increases the *D*-layer ionization. The more intense the x-ray radiation, the more dense the layer becomes, and higher frequencies get blocked. The rest of the time, without the increased x-ray radiation from a solar flare, the daytime *D* layer will only block the lowest HF frequencies, while higher frequencies will lose some of their energy. If the radio signal makes it through the *D* layer, it then reaches the *E* layer. If the *E* layer is highly ionized (say, during an *Es* condition) and the frequencies are low enough, the signal will be refracted back to Earth, much like a light beam from a flashlight is refracted by a mirror.

Lower HF signals tend to be refracted by the *E* layer, especially at night. During the day, the *D* layer generally blocks these lower HF signals. Higher frequencies, however, punch through the *E* layer and reach the *F* layer. If they are at or below the MUF, they too are refracted back to Earth, but at greater distances from their sources. This is called *skip propagation*. Since solar radiation has to travel the farthest to get the *D* Layer,

Optimum Working Frequencies (MHz) - For March 2005 - Flux = 80, SSN = 20- Created by NW7US

UTC TO/FROM US WEST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	21	20	19	16	15	14	13	12	11	11	10	10	10	11	16	19	20	21	22	22	23	23	23	22
NORTHERN SOUTH AMERICA	29	28	26	24	22	20	18	17	16	15	14	14	13	13	19	21	23	25	26	27	28	29	29	29
CENTRAL SOUTH AMERICA	28	26	24	22	20	18	17	16	15	14	14	13	13	14	21	24	25	26	27	28	28	29	29	29
SOUTHERN SOUTH AMERICA	30	29	27	25	23	21	19	18	17	16	15	14	14	13	16	21	24	27	28	29	30	31	31	30
WESTERN EUROPE	10	9	9	9	8	8	8	9	9	9	8	8	8	14	16	17	18	18	18	17	16	15	13	10
EASTERN EUROPE	9	9	10	12	13	10	10	9	9	9	9	8	8	12	14	15	15	15	15	14	14	13	13	11
EASTERN NORTH AMERICA	23	22	20	15	14	13	12	12	11	11	11	10	10	16	20	22	23	24	25	25	25	25	25	24
CENTRAL NORTH AMERICA	13	13	12	11	8	7	7	7	6	6	6	6	6	6	9	11	12	13	13	14	14	14	14	14
WESTERN NORTH AMERICA	7	7	7	6	5	4	4	3	3	3	3	3	3	3	3	5	6	7	7	7	7	7	7	7
SOUTHERN NORTH AMERICA	22	21	20	18	15	14	13	12	12	11	11	10	10	10	14	18	20	21	22	23	23	23	23	23
NORTHERN AFRICA	10	10	9	9	9	9	8	9	9	9	8	8	8	14	16	17	18	19	19	17	15	12	11	11
CENTRAL AFRICA	14	13	12	12	10	10	9	9	9	9	8	8	8	14	16	17	18	18	19	19	18	17	16	15
SOUTH AFRICA	19	18	17	13	12	12	11	11	10	10	10	10	10	17	20	21	22	23	24	24	24	24	23	21
MIDDLE EAST	9	9	8	8	10	10	10	9	9	9	8	8	8	13	15	16	17	17	15	11	10	10	9	9
JAPAN	20	20	19	19	18	16	14	10	10	10	9	9	9	8	8	8	9	9	8	8	14	17	18	19
CENTRAL ASIA	20	20	19	19	18	16	14	10	10	10	9	9	9	8	8	8	13	13	12	12	11	11	16	20
INDIA	12	13	13	13	13	13	10	9	9	9	9	8	8	8	8	8	8	8	8	9	10	11	12	12
THAILAND	17	19	19	18	17	16	14	10	10	9	9	9	9	8	8	8	13	15	14	13	13	12	11	13
AUSTRALIA	25	26	27	28	27	25	21	19	18	17	16	15	14	14	13	13	16	15	15	14	15	18	21	23
CHINA	18	19	19	18	17	16	14	10	10	9	9	9	9	8	8	8	9	9	9	8	8	8	14	16
SOUTH PACIFIC	29	30	30	29	28	25	23	21	19	18	17	16	15	14	14	13	15	14	14	19	22	25	27	28

UTC TO/FROM US MIDWEST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	24	23	21	19	18	16	15	14	13	13	12	11	11	16	20	22	23	24	25	26	26	26	26	25
NORTHERN SOUTH AMERICA	26	26	24	22	20	19	17	16	15	14	13	13	12	15	18	20	22	23	24	25	26	26	27	27
CENTRAL SOUTH AMERICA	28	26	24	22	20	18	17	16	15	14	14	14	14	20	22	24	25	26	27	28	28	29	29	28
SOUTHERN SOUTH AMERICA	30	29	27	24	22	20	19	18	16	15	15	14	14	16	20	23	26	27	29	30	30	31	30	30
WESTERN EUROPE	10	9	9	9	8	8	8	9	8	8	8	10	15	16	18	18	19	18	18	17	17	15	14	10
EASTERN EUROPE	9	9	9	8	8	9	9	9	9	8	8	8	14	16	17	17	17	17	16	16	15	14	12	10
EASTERN NORTH AMERICA	17	15	13	11	11	10	9	9	8	8	8	8	8	13	15	16	17	18	18	18	18	18	18	17
CENTRAL NORTH AMERICA	8	7	7	5	5	4	4	4	4	3	3	3	3	5	6	7	8	8	8	8	8	8	8	8
WESTERN NORTH AMERICA	13	13	12	11	8	8	7	7	7	6	6	6	6	6	9	11	12	13	14	14	14	14	14	14
SOUTHERN NORTH AMERICA	16	15	14	12	11	10	9	9	8	8	8	7	7	8	12	13	15	15	16	16	17	17	16	16
NORTHERN AFRICA	13	13	11	10	10	9	9	9	9	8	8	11	15	17	18	19	20	20	20	20	20	16	15	14
CENTRAL AFRICA	14	14	11	10	10	9	9	9	9	8	8	11	15	17	18	19	20	20	20	20	20	18	17	16
SOUTH AFRICA	19	18	17	16	15	14	14	14	14	13	13	12	20	24	27	28	29	30	30	29	28	25	23	21
MIDDLE EAST	9	9	9	8	8	9	9	9	9	8	8	10	15	17	18	18	19	18	16	12	11	10	10	9
JAPAN	19	19	18	17	15	11	10	10	9	9	9	9	8	8	9	9	9	8	8	8	14	16	18	19
CENTRAL ASIA	19	18	18	16	15	11	10	10	9	9	9	8	8	8	12	14	13	12	12	11	11	11	16	19
INDIA	8	8	9	9	9	9	9	9	9	8	8	8	9	9	9	9	8	8	8	8	8	8	8	8
THAILAND	17	18	17	16	14	10	10	9	9	9	9	8	8	8	14	16	16	15	14	13	13	12	11	12
AUSTRALIA	25	26	28	26	24	20	19	17	16	15	15	14	13	13	13	17	16	15	15	14	15	19	21	23
CHINA	17	18	17	16	14	10	10	9	9	9	9	8	8	8	10	10	9	9	9	8	8	8	13	16
SOUTH PACIFIC	30	30	29	27	25	23	21	19	18	17	16	15	14	14	13	15	14	14	16	21	24	26	28	29

UTC TO/FROM US EAST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	20	18	17	15	14	13	12	11	11	10	10	9	12	14	16	18	19	20	21	21	21	21	21	20
NORTHERN SOUTH AMERICA	23	23	21	19	18	16	15	14	13	12	12	11	12	15	17	19	20	21	22	23	23	24	24	24
CENTRAL SOUTH AMERICA	28	25	23	21	19	18	17	16	15	14	13	13	18	21	22	24	25	26	27	28	28	28	28	28
SOUTHERN SOUTH AMERICA	29	28	26	24	22	20	18	17	16	15	14	14	16	20	22	25	26	28	29	30	30	30	30	30
WESTERN EUROPE	9	9	9	8	8	8	8	8	8	8	12	15	17	18	18	19	19	18	18	17	16	15	13	10
EASTERN EUROPE	9	9	9	8	8	8	9	8	8	8	11	15	17	18	18	18	18	17	17	16	15	14	10	10
EASTERN NORTH AMERICA	8	7	6	5	5	5	4	4	4	4	4	3	6	7	8	8	9	9	9	9	9	9	9	8
CENTRAL NORTH AMERICA	17	16	14	12	11	10	10	9	9	9	8	8	9	14	16	17	18	19	19	19	19	19	19	18
WESTERN NORTH AMERICA	23	22	20	15	14	13	13	12	12	11	11	11	10	16	20	22	23	24	25	25	25	25	25	24
SOUTHERN NORTH AMERICA	19	18	16	15	13	12	12	11	10	10	9	9	9	13	16	18	19	20	20	21	21	21	20	20
NORTHERN AFRICA	14	13	13	12	12	11	11	11	11	10	15	20	22	23	24	25	25	25	24	23	21	18	17	15
CENTRAL AFRICA	15	14	13	13	12	12	11	11	11	10	15	20	22	23	24	25	26	25	25	23	21	20	18	17
SOUTH AFRICA	19	18	17	16	15	14	14	15	14	14	13	19	23	25	27	29	30	30	30	29	28	25	23	21
MIDDLE EAST	12	11	10	10	9	9	9	9	8	8	13	16	18	19	20	20	20	21	20	18	15	14	13	13
JAPAN	18	17	14	11	10	10	9	9	9	9	8	8	10	10	9	9	9	8	8	8	12	16	17	18
CENTRAL ASIA	17	16	14	10	10	9	9	9	9	8	8	8	14	16	15	14	13	12	12	11	11	11	14	18
INDIA	8	8	8	9	9	9	9	9	8	8	8	13	14	14	14	14	14	13	13	12	12	10	9	9
THAILAND	15	15	11	10	10	9	9	9	8	8	8	12	15	17	18	18	17	15	14	13	13	12	12	11
AUSTRALIA	26	27	25	22	20	19	17	16	15	15	14	13	13	15	19	17	16	15	14	14	16	19	22	24
CHINA	17	15	12	10	10	9	9	9	9	8	8	10	15	12	10	10	9	9	9	9	8	8	9	15
SOUTH PACIFIC	30	29	27	25	23	21	19	18	17	16	15	14	14	16	15	14	14	13	19	23	25	27	29	30

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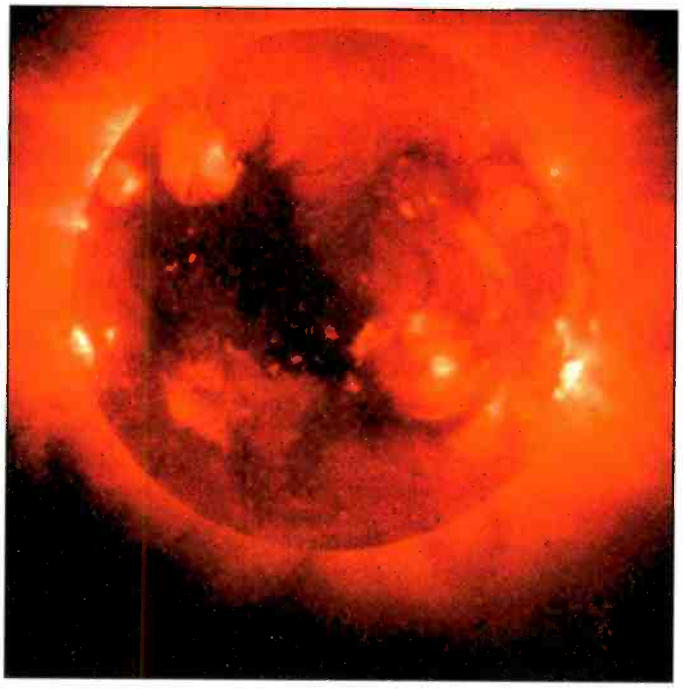

This image of the Sun, captured on February 7, 2002, by the presently operating SOlar and Heliospheric Observatory (SOHO) spacecraft shows a coronal hole (the large dark region) that has just rotated past the most favorable position to send high-speed solar wind particles toward Earth. Gusts of solar wind pour out of these holes and strike Earth's magnetic field and trigger moderate geomagnetic disturbances. (Source: SOHO-EIT Consortium, ESA, NASA)

absorption is usually minimal. Unless there is a major solar radiation storm, we have minimal daytime absorption and good skip propagation.

Then comes the end of the daylight hours. At sunset, solar radiation no longer strikes the ionosphere and ionization stops. Without this solar radiation, the layers of ionization decrease in density by a process called *recombination*. This causes the MUF to decrease as well, which is why by total darkness the highest HF bands close down. Those frequencies do not get refracted, but continue on out into space.

The *D* layer is the first layer where ionization stops. Since it is closest to the ground, sunlight no longer reaches it, while higher levels of the atmosphere remain in sunlight. Think about how you can see a passing satellite by the sunlight reflected off its surface, while you are standing in darkness; it's dark on the ground, but the satellite is still being illuminated. As the *D* layer goes into recombination, the electron density decreases as does the absorption rate.

During the twilight hours the *D* layer rapidly looses its ionization and does not absorb radio signals passing through it, while the *E* and *F* layers are still being ionized by sunlight. This makes for about 45 to 60 minutes of stronger signal propagation on a wide range of HF frequencies. As the ionization decreases, lower and lower frequencies start to punch through the *D* layer with almost no signal attenuation. Yet the MUF is still high, allowing long-distance skip propagation. Then, when the Sun is blocked from illuminating the *E* and *F* layers, the MUF can drop dramatically and very quickly (within minutes). This twilight zone, where the Sun is exactly 12 degrees below the horizon, is called the *grayline*, or in astronomical terms, the

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terminator. The same principles apply at sunrise; the upper ionosphere begins to become ionized, while the *D* layer is still dark and low in density, offering free passage of very low HF signals, even MW signals.

Signals that are aimed along a path that stays within the grayline often experience significant improvements in propagation. This is what we refer to as *grayline propagation*, and it's a very exciting way to hear exotic DX signals. These signals may be coming in from the long path as well as the short path, but always along this grayline.

As we move closer to Solar Cycle 23's end, and the year or so of solar activity minimum, grayline propagation brings exciting DX from many rare areas of the world. Tune around the lower shortwave bands about an hour before sunrise and again right before sunset to look for these long-distance signals. Of course, grayline DX will occur on most of the HF spectrum, but is quite noticeable on these lower shortwave bands, since DX signals on these bands are rare.

Current Cycle 23 Progress

The Dominion Radio Astrophysical Observatory at Penticton, BC, Canada, reports a 10.7-centimeter observed monthly mean solar flux of 113 for November 2004, quite a bit higher than 106 for October. The 12-month smoothed 10.7-centimeter flux centered on May 2004 is 109, just down from April's 112. The predicted smoothed 10.7-centimeter solar flux for January 2005 is about 80, give or take about 16 points.

The Royal Observatory of Belgium reports that the monthly mean observed sunspot number for November 2004 is 44, down four points from October's 48. The lowest daily sunspot value during November was recorded on November 21 at 26, which is considerably higher than the October 10 count of zero. The highest daily sunspot count was 76 on November 1. The 12-month running smoothed sunspot number centered on May 2004 is 44, down two points from April's 46. A smoothed sunspot count of 30 to 33 is expected for March 2005 by the SIDC. The SEC predicts the sunspot count to be 22, give or take about 12 points.

The observed monthly mean Ap index for November 2004 is 26, a very large jump up from October's 9, and even higher than July's 23. The 12-month smoothed Ap index centered on May 2004 is 14, down from April's 16. Expect the overall geomagnetic activity to be quiet to active during most days in March, though there is a possibility for a strong geomagnetic storm on a couple of days since we're getting close to the Spring Equinox.

HF Propagation

March is one of the optimal DX months. As the Spring Equinox approaches, the grayline begins to run straight north and south. The period of darkness is growing shorter, causing the average daily MUFs to rise a bit. Noise levels are still low, at the same time, making for reliable DX. The solar activity is moderate, and holds enough energy to keep the mid-HF spectrum alive with signals. General conditions are expected to be good to excellent for HF propagation throughout March.

Sixteen meters will only occasionally remain open into the late evening. Daytime paths will not degrade much until midsummer. You will see consistently early closures or completely dead conditions at times, if you live closer to the North Pole (high latitudes).

Twenty-two and 19 meters will remain in good shape. Both short and long path circuits will often be reliable and solid. Nighttime paths are rarer than last year at this time. If the flux is high enough, expect good openings during the evening hours in the United States, which are sunrise hours across Russia, Africa, and both the Near and Far East. Expect a fair amount of short- and long-path DX from these areas of the world.

Between sunset and midnight, expect occasional DX openings on all bands between 15 and 41 meters when solar activity is high. Conditions should favor openings from the east and south. These bands should peak for openings from Europe and Africa near midnight.

From midnight to sunrise, expect optimum DX conditions on 31 through 90

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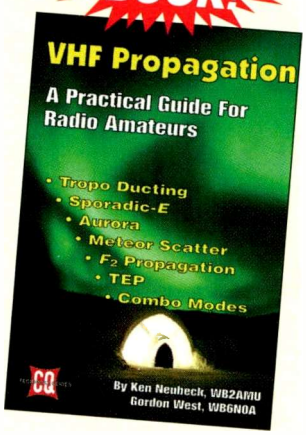

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meters and, occasionally, 120 meters. Conditions should favor openings from the west and south. Some rather good openings on 19 and 22 meters should also be possible from the south and west during this time.

Noise levels are slowly increasing as we move toward spring. Geomagnetic storms will increase, disrupting the mid- and high-latitude ionosphere. During the Spring Equinox, Earth's magnetic field is sufficiently perturbed by solar wind particles flowing into the auroral zone (between 50 and 70 degrees north geographic latitude) to cause the ionosphere to be depleted. During days of typical post-solar cycle maximum disturbance (coronal hole mass ejections, high-speed solar winds with a southerly oriented interplanetary magnetic field), an increase in geomagnetic storms will degrade many paths, while VHF openings off the auroral zone may increase.

As spring and summer approach in the Northern Hemisphere, daytime MUFs continue to drop, while the nighttime MUFs will start to increase. At the same time, the Ap is on the rise, so take advantage of the current excellent conditions while they last, and listen to the world! Look for grayline DX in the mornings and evenings on lower frequencies.

VHF Ionospheric Openings

The possibilities for ionospheric openings on the VHF bands usually improve during March and the spring months. Many of the solar-ionospheric relationships that can produce ionospheric openings on the VHF bands tend to peak during equinoctial periods.

A seasonal increase in short-skip openings due to *Es* propagation generally takes place during March, and an occasional low-VHF opening may be possible during this month. *Es* openings most often occur during the daylight hours over distances between about 1,000 and 1,400 miles. There is also a good chance for an increase in widespread auroral activity during March, accompanied by auroral-scatter-type openings on VHF up to 2 meters.

Conditions should be optimal during March for transequatorial (TE) scatter propagation between the southern tier states and countries deep in South America. The best time for TE openings should be between 8 and 11 p.m. local time. Check TV Channel 2 for DX from South America.

I'd Like To Hear From You

You can join in with others in discussing space weather, propagation, and shortwave or VHF listening at http://hfradio.org/forums/. Be sure to check out the latest conditions, as well as the educational resources about propagation, which I have put together for you at http://prop.hfradio.org/. I also provide a WAP/WML resource for wireless devices. If you want the latest propagation information like the solar flux, Ap reading, and so forth, check out http://wap.hfradio.org/, the wireless version of my propagation site.

Please don't hesitate to write and let me know about any interesting propagation you've noticed. Do you have questions about propagation? I look forward to hearing from you. Turn on your favorite radio and enjoy the great DX season on the medium and short waves. Happy hunting! ■

by Tomas Hood, NW7US, pc-prop-man@hfradio.org

Reviewing Propagation And Space Weather Terms—Part III The Interplanetary Magnetic Field (IMF)

This month we'll look at the interplanetary magnetic field, or IMF, and learn how it affects space weather. The Sun, and each planet, has a magnetic structure, and of course the Earth has a north pole and a south pole. Magnetic-field lines run from pole to pole, forming a donut shape of magnetic flux energy. The Sun has a magnetic structure, as well. It can become quite complex, with several *intertwined* poles. The Sun even *reverses* its north and south pole each solar cycle.

The Sun's magnetic field permeates the entire solar system, and beyond. This region, which stretches from the Sun outward past the end of the solar system, is called the *heliosphere*. The magnetic field that originates in the Sun and stretches out through the heliosphere is called the *interplanetary magnetic field*. The IMF interacts with the Earth and is a primary cause of space weather.

The IMF sprawls out away from the Sun in the form of a huge "current sheet," a vast expanding surface where complex magnetic-field lines run from one solar pole far out into the solar system, arching back again along this sheet to return to the Sun's other pole. These magnetic field lines therefore have polarities that change from north (plus) to south (minus). An IMF flux line that is oriented "northward" is one oriented toward the Sun, while one oriented "southward" is one directed away from the Sun. The huge solar current sheet that expands away from the sun is 10,000 km thick and extends past the orbit of Pluto! The entire heliosphere is organized around this giant sheet, which carries an electrical current that is about 16 orders of magnitude less than that of the current carried in an ordinary light bulb.

Ordinarily, the current sheet circles the Sun's equator, spreading out in a wavy sheet that might be said to resemble a dancer's

The Ap Index And Understanding Propagation Terminology

The Ap index, or Planetary A index, is a 24-hour averaging of the Planetary K index. The Planetary K index is an averaging of worldwide readings of Earth's geomagnetic field. High indices (Kp > 5 or Ap > 20) mean stormy conditions with an active geomagnetic field. The more active, the more unstable propagation is, with possible periods of total propagation fade-out. Especially around the higher latitudes and especially at the Polar Regions, where the geomagnetic field is weak, propagation may disappear completely. Extreme high indices may result in aurora propagation, with strongly degraded long distance propagation at all latitudes. Low indices result in relatively good propagation, especially noticeable around the higher latitudes, when transpolar paths may open up. Maximum K-index is 9, and the A-index can exceed well over 100 during very severe storm conditions, with no maximum.

Classification of A-indices is as follows:

A0–A7 = quiet	A30–A49 = minor storm
A8–A15 = unsettled	A50–A99 = major storm
A16–A29 = active	A100–A400 = severe storm

Solar Flux (SFI): This flux number is obtained from the amount of radiation on the 10.7-cm band (2800 MHz). It is closely related to the amount of ultraviolet radiation, which is needed to create the ionosphere. Solar Flux readings are more descriptive of daily conditions than the Sunspot Number. The higher the Solar Flux (and, therefore, the higher the Sunspot Number), the stronger the ionosphere becomes, supporting refraction of higher frequencies.

Ionosphere: A collection of ionized particles and electrons in the uppermost portion of the Earth's atmosphere, which is formed by the interaction of the solar wind with the very thin air particles that have escaped Earth's gravity. These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies, with these critical frequencies varying with the degree of ionization. As a result, radio waves having frequencies higher than the Lowest Usable Frequency (LUF) but lower than the Maximum Usable Frequency (MUF) are propagated over large distances.

Sunspot Number (SSN): Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Sunspots appear as dark spots on the surface of the Sun. Temperatures in the dark centers of sunspots drop to about 3700° K (compared to 5700° K for the surrounding photosphere). This difference in temperatures makes the spots appear darker than elsewhere. Sunspots typically last for several days, although very large ones may last for several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually occur in a group, with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the sunspots (called the "umbra"). The field is weaker and more horizontal in the lighter part (the "penumbra").

Galileo made the first European observations of sunspots in 1610. The Chinese and many other early civilizations have records of sunspots. Daily observations were started at the Zurich Observatory in 1749; continuous observations were begun in 1849.

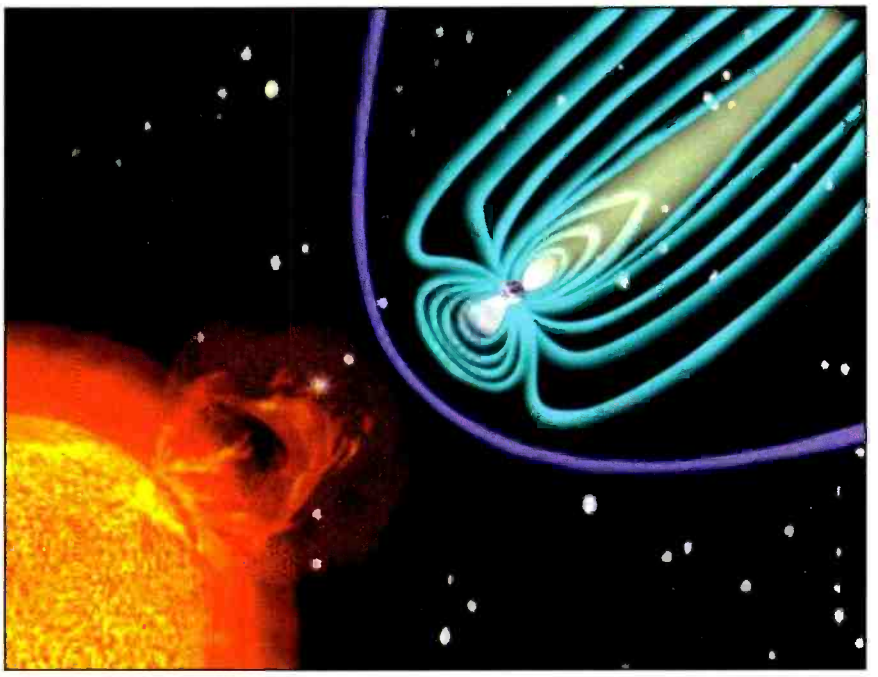
The sunspot number is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The "sunspot number" is then given by the sum of the number of individual sunspots and 10 times the number of groups. Since most sunspot groups have, on average, about 10 spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see. Monthly averages (updated monthly) of the sunspot numbers show that the number of sunspots visible on the sun waxes and wanes with an approximate 11-year cycle.

For more information, see http://prop.hfradio.org.

skirt that flies up while the dancer is spinning around. As Earth orbits the Sun, it dips in and out of the main structure of this wavy current sheet. On one side of this sheet, the Sun's magnetic field lines point northward, or toward the Sun. On the other side they point southward, or away from the Sun.

South-pointing solar magnetic-field flux lines tend to connect with Earth's own magnetic field (think of holding two bar magnets together, with one bar magnet's north pole against the other bar's south pole). Solar-wind energy can then penetrate the local space around our planet and fuel geomagnetic storms. (We report IMF orientation using the B_z [B sub Z] index. When the B_z is negative, it indicates a southerly oriented IMF.)

Each solar cycle, the Sun *reverses* it main polarity. During Cycle 23, the Sun's flip in March 2000 caused the predominant orientation of the IMF to be negative. This has contributed to the more geomagneticly stormy decline of this cycle as compared with the last solar cycle.



An artist's view of a coronal mass ejection (CME) heading toward the Earth. As the cloud of plasma riding the solar wind and interplanetery magnetic field (IMF) reaches the magnetosphere, there is great compression as the magnetosphere opposes the shock wave. (Source: NOAA/SEC)

Solar Wind

Riding the IMF is the solar wind. The Sun is a huge ball of energy. A great amount of that energy is released out away from the Sun through various events and mechanisms. Solar flares, coronal mass ejections (CMEs), and coronal holes are just some examples of the release of energy and material from the Sun out into the heliosphere.

Have you seen a water sprinkler that has a rotating arm consisting of many little holes through which water is sprayed in small jets? These water jets cause the arm to rotate in a continuous circle. As you watch this rotation from above, you can see the water spreading outward in an expanding, arching spiral. The material spewing out, away from the Sun, resembles this arching. Because the Sun is rotating, solar material (i.e., plasma and protons) will arch out away from the Sun, riding on the magnetic field lines of the IMF and current sheet.

Space Weather And The Earth

As the Earth moves through the solar wind and the IMF, clouds of solar plasma and material bombard the magnetosphere. Depending on the orientation of the IMF at the given moment, that material may or may not penetrate into our atmosphere. Whenever a reconnection

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UTC TO/FROM US WEST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	22	22	22	20	18	17	15	14	13	12	12	11	11	13	16	18	19	20	21	22	22	22	23	23
NORTHERN SOUTH AMERICA	28	28	28	25	23	21	19	18	17	16	15	14	14	15	19	21	23	24	26	27	27	28	28	28
CENTRAL SOUTH AMERICA	29	26	24	22	20	18	17	16	15	14	14	15	15	17	21	24	26	27	29	29	30	30	30	29
SOUTHERN SOUTH AMERICA	27	24	22	20	18	17	16	15	14	14	13	13	14	15	17	21	23	25	27	28	29	30	30	29
WESTERN EUROPE	15	12	10	9	13	15	11	10	9	9	11	15	16	17	18	19	19	19	19	18	18	17	17	16
EASTERN EUROPE	9	9	9	8	12	15	15	13	10	9	13	15	16	17	17	18	18	18	17	16	15	14	10	10
EASTERN NORTH AMERICA	25	24	23	22	20	18	17	15	14	13	13	12	14	18	20	22	24	25	25	26	26	26	26	26
CENTRAL NORTH AMERICA	14	14	13	13	12	11	10	9	8	8	7	7	7	8	10	12	13	13	14	14	14	14	15	14
WESTERN NORTH AMERICA	8	7	7	7	7	6	5	5	4	4	4	4	3	3	5	6	6	7	7	7	7	8	8	8
SOUTHERN NORTH AMERICA	24	23	23	22	21	19	17	16	15	14	13	12	11	12	15	18	19	21	22	23	23	24	24	24
NORTHERN AFRICA	13	12	12	11	10	10	11	10	10	9	9	14	16	18	18	19	20	20	20	20	19	17	16	14
CENTRAL AFRICA	16	15	14	13	13	13	10	10	9	9	10	14	16	17	18	19	19	20	20	20	20	20	19	18
SOUTH AFRICA	18	17	16	15	14	14	15	14	13	12	12	11	17	20	21	23	24	24	25	25	25	23	21	20
MIDDLE EAST	11	10	10	10	15	16	14	12	10	9	12	15	16	17	18	18	19	19	18	16	14	13	12	12
JAPAN	20	21	20	20	19	19	17	16	13	12	11	10	10	10	9	11	11	10	10	13	16	18	19	20
CENTRAL ASIA	21	21	20	20	19	19	17	16	13	12	11	10	10	9	9	14	16	15	14	13	13	14	17	19
INDIA	16	17	17	17	17	16	16	15	13	10	9	12	12	9	9	9	9	8	8	10	13	14	15	16
THAILAND	17	19	20	20	19	18	17	16	13	11	10	10	9	9	12	16	17	17	16	15	14	13	12	14
AUSTRALIA	27	28	30	30	30	29	28	26	23	21	20	18	17	16	15	14	16	15	14	14	15	20	23	25
CHINA	19	20	20	20	19	18	17	16	13	11	10	10	9	9	13	12	11	11	10	10	10	14	17	18
SOUTH PACIFIC	31	31	31	30	30	29	27	24	21	20	18	17	16	15	14	14	13	13	13	21	25	27	29	30

UTC TO/FROM US MIDWEST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	25	25	24	22	20	19	17	16	15	14	13	12	13	16	19	21	22	23	24	25	25	26	26	26
NORTHERN SOUTH AMERICA	26	26	25	23	21	19	18	16	15	14	14	13	13	16	18	20	21	23	24	25	25	26	26	26
CENTRAL SOUTH AMERICA	28	26	23	21	20	18	17	16	15	14	14	15	16	20	22	24	26	27	29	29	30	30	30	29
SOUTHERN SOUTH AMERICA	27	24	22	20	19	17	16	15	14	14	13	13	14	17	20	22	24	26	27	28	29	30	30	29
WESTERN EUROPE	14	10	10	9	9	11	10	10	9	9	14	16	17	18	19	20	20	20	19	19	18	18	17	16
EASTERN EUROPE	10	9	9	9	11	10	10	9	9	9	14	16	17	18	19	19	19	18	18	17	17	16	14	10
EASTERN NORTH AMERICA	18	18	17	16	14	13	12	11	10	10	9	9	11	13	15	16	17	18	18	19	19	19	19	19
CENTRAL NORTH AMERICA	8	8	8	7	7	6	6	5	5	4	4	4	4	6	7	7	8	8	8	9	9	9	9	9
WESTERN NORTH AMERICA	14	14	14	13	12	11	10	9	9	8	7	7	7	8	10	12	13	13	14	14	15	15	15	15
SOUTHERN NORTH AMERICA	17	16	16	15	14	13	12	11	10	9	9	8	8	10	12	13	14	15	16	16	16	17	17	17
NORTHERN AFRICA	17	16	15	14	13	12	11	10	10	9	12	16	18	19	20	20	21	21	21	21	21	21	20	19
CENTRAL AFRICA	17	15	14	13	12	12	11	10	10	9	13	16	18	19	20	20	21	21	21	21	21	21	20	18
SOUTH AFRICA	18	17	16	15	14	14	14	17	16	15	15	17	21	24	26	28	29	30	29	27	25	23	21	19
MIDDLE EAST	12	11	10	10	12	11	10	10	9	9	14	16	18	19	19	20	20	20	19	18	16	14	13	12
JAPAN	20	20	20	19	18	16	14	12	11	10	10	10	9	13	12	11	10	10	10	13	16	18	19	20
CENTRAL ASIA	20	20	19	19	18	16	13	11	11	10	10	9	10	15	17	18	16	15	14	13	13	13	17	20
INDIA	11	13	14	15	15	14	10	10	9	9	12	15	16	15	15	14	13	11	9	9	9	8	8	8
THAILAND	17	19	19	18	17	16	13	11	10	10	9	9	14	16	17	18	19	17	16	15	14	13	12	14
AUSTRALIA	28	29	30	30	29	27	25	22	21	19	18	17	16	15	16	17	16	15	14	14	16	21	24	26
CHINA	19	19	19	18	17	16	13	10	10	10	9	9	14	15	13	12	11	10	10	10	9	14	17	18
SOUTH PACIFIC	31	31	30	30	29	27	24	22	20	18	17	16	15	14	14	13	13	13	16	23	26	28	29	30

UTC TO/FROM US EAST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	20	20	19	17	16	14	13	12	11	11	10	10	12	14	16	17	18	19	20	20	20	21	21	21
NORTHERN SOUTH AMERICA	23	23	21	19	18	16	15	14	13	12	12	11	13	15	17	18	20	21	22	22	23	23	23	23
CENTRAL SOUTH AMERICA	28	25	23	21	19	18	17	16	15	14	14	15	18	21	23	24	26	27	28	28	29	29	29	29
SOUTHERN SOUTH AMERICA	26	23	21	20	18	17	16	15	14	14	13	13	17	20	22	24	25	26	27	28	29	29	29	28
WESTERN EUROPE	12	11	10	10	9	9	10	9	9	12	15	16	18	19	19	20	20	19	19	19	18	17	16	14
EASTERN EUROPE	12	10	9	10	11	11	10	10	9	13	16	17	19	19	19	19	19	19	18	18	17	17	16	14
EASTERN NORTH AMERICA	9	8	8	7	7	6	5	5	5	4	4	5	6	7	7	8	8	9	9	9	9	9	9	9
CENTRAL NORTH AMERICA	19	18	18	16	15	14	13	12	11	10	10	9	12	14	16	17	18	19	19	20	20	20	20	20
WESTERN NORTH AMERICA	25	25	24	22	20	18	17	16	15	14	13	12	14	18	20	22	24	25	25	26	26	26	26	26
SOUTHERN NORTH AMERICA	20	20	19	18	16	15	14	13	12	11	10	10	11	13	15	17	18	19	20	20	20	21	21	21
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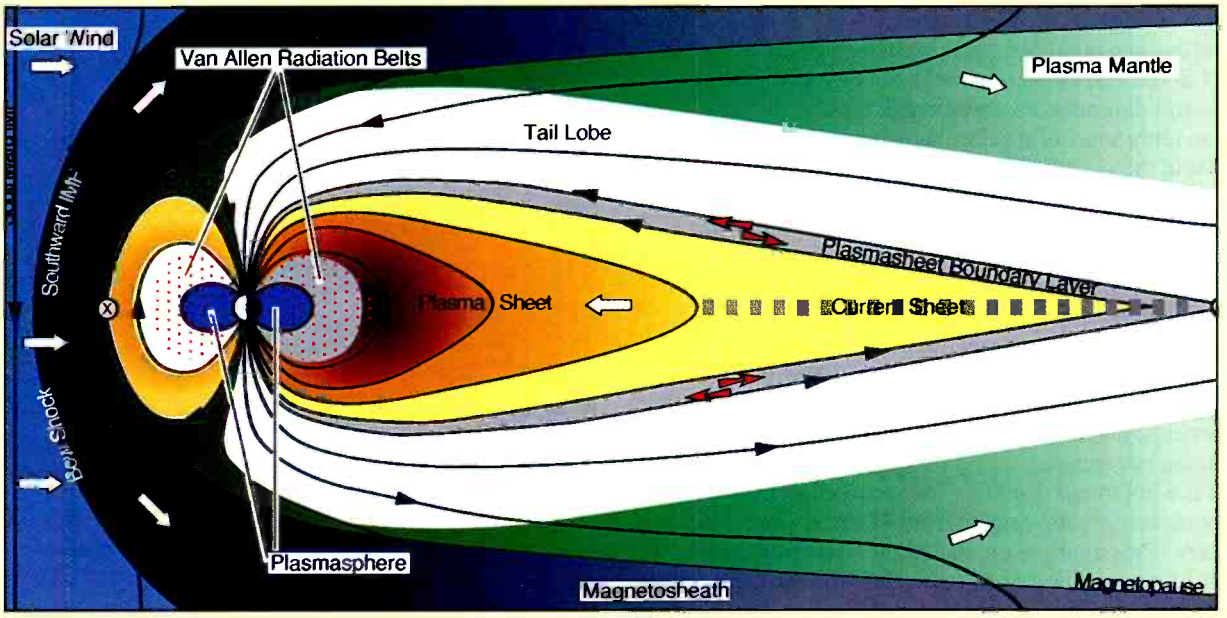
CENTRAL AFRICA	17	16	15	14	13	12	14	13	12	13	17	20	22	23	25	25	26	26	25	25	24	22	20	18
SOUTH AFRICA	18	17	16	15	14	14	14	16	15	15	16	19	22	24	26	27	28	29	29	27	25	23	21	19
MIDDLE EAST	15	14	13	13	12	11	11	10	10	12	15	17	19	20	20	21	21	21	21	21	21	19	18	16
JAPAN	20	19	18	16	13	12	11	11	10	10	9	14	13	12	12	11	10	10	9	13	16	18	19	20
CENTRAL ASIA	19	18	17	15	12	11	11	10	10	9	11	15	17	18	19	18	16	15	14	13	13	12	16	19
INDIA	9	9	8	8	11	11	10	10	9	12	15	17	18	18	17	17	17	16	16	15	13	11	9	9
THAILAND	16	18	16	13	11	11	10	10	9	10	15	17	18	19	20	20	19	18	16	15	14	13	13	12
AUSTRALIA	28	30	29	28	26	24	22	20	18	17	16	15	15	18	17	16	15	15	14	13	17	21	24	27
CHINA	19	18	17	14	12	11	10	10	9	9	14	16	18	17	14	12	11	11	10	10	9	13	16	18
SOUTH PACIFIC	30	30	29	28	25	23	21	18	17	16	15	14	14	13	13	13	12	12	20	24	27	28	29	30



Schematic of the Earth's magnetosphere, with principal particle regions (adapted from T. W. Hill). The direction to the Sun is to the left. The interplanetary magnetic field, imbedded in the solar wind, impinges upon the magnetopause. If it is southward, as here, it connects to the Earth's magnetic field at the X-line (shown as a circle with X inside), resulting in a region of field lines connecting from the Earth to deep space. Plasma from the solar wind enters via the cusp, becomes trapped in the plasma sheets, and eventually precipitates to Earth or is lost down the magnetotail. (Source: NASA)

occurs between the Sun's magnetic field lines and Earth's, solar materials can rain into our atmosphere. This material will align with the Earth's magnetic-field lines and ride these downward toward our two magnetic poles. This spawns aurora.

The IMF and the pressure of the solar wind always influence the magnetosphere. Whenever the solar wind speed increases, the magnetosphere become more compressed on the side facing the Sun. On the other side of the Earth, the magnetosphere will be stretched far out, away from the Sun. As the speed of the solar wind decreases, the magnetosphere will decompress. Whenever this compression and decompression happens in rapid waves, electrical currents are generated in the Earth's magnetic fields. This causes geomagnetic disturbances.

Geomagnetic storms cause a degradation of shortwave radio signal propagation as a result of ionospheric recombination. This recombination is similar to what takes place during the hours of darkness, with a lowering of the frequencies each ionospheric layer can refract.

On the other hand, a stormy geomagnetic field can spark auroras, which can support aurora-mode VHF propagation. Geomagnetic storms can cause long-term (hours to days) degradation, or depression, of the maximum usable frequencies (MUFs), reducing the critical frequencies by as much as 50 percent of normal.

We saw quite a dramatic example of all of these dynamics during the geomagnetic storm period of 15–20 January 2005. A series of strong solar flares, ranging from M- to X-class in intensity, unleashed a series of coronal mass ejections directed squarely toward the Earth. When the massive plasma clouds arrived at the Earth, after riding the IMF at a speed exceeding 1500 kilometers per second, it caused very strong compression of the magnetosphere and spawned severe geomagnetic storms. This caused a general degradation of worldwide shortwave propagation, but spawned great visual aurora. VHF enthusiasts enjoyed the propagation off of the aurora-induced E-layer ionization.

Current Cycle 23 Progress

The Royal Observatory of Belgium reports that the monthly mean observed sunspot number for December 2004 is 18, a huge drop from November's 43.7. The lowest daily sunspot value during December, recorded on December 15, was 8. The highest daily sunspot count was 32, recorded on December 1. These high and low marks are significantly lower than the spread in November. The 12-month running smoothed sunspot number centered on June 2004 is 44, down three tenths from May's 44.3. A smoothed sunspot count of 30 to 33 is expected by the SIDC for April 2005. The SEC predicts the sunspot count to be 20, give or take about 12 points.

The Dominion Radio Astrophysical Observatory at Penticton, BC, Canada reports a 10.7-cm observed monthly mean solar flux of 94.6 for December 2004, a bit lower than November's 113.2. The 12-month smoothed 10.7-cm flux centered on June 2004 is 107.2, just down from May's 109.2. The predicted smoothed 10.7-cm solar flux for April 2005 is about 82, give or take about 16 points.

The observed monthly mean planetary A index (Ap) for December 2004 is 11, a nice drop from November's 26. The 12-month smoothed Ap index centered on June 2004 is 14, about the same as for May. Expect the overall geomagnetic activity to be quiet to active during most days in April, with some isolated periods of storm level activity, since we are in the equinoctial season.

HF Propagation—Great DX Openings!

As we move into spring in the Northern Hemisphere, we experience great DX

openings from around the world on the high frequencies. This is because the Sun is mostly overhead over the equator, creating equal day and night periods in both hemispheres. The Vernal Equinox at the end of March marks the day when the hours of daylight and darkness are about equal around the world. This creates an ionosphere of similar characteristics throughout more of the world than is possible during other times when it is summer in one hemisphere and winter in the other and there are extreme differences in the ionosphere. This equalization of the ionospheric which takes place during the equinoctial periods (autumn and spring) is responsible for optimum DX conditions and starts late in February and lasts through late April.

The improvement in propagation is most noticeable on long circuits between the Northern and Southern Hemispheres. During this season conditions are also optimum for long-path and short-path openings, and during gray-line twilight periods associated with sunrise and sunset.

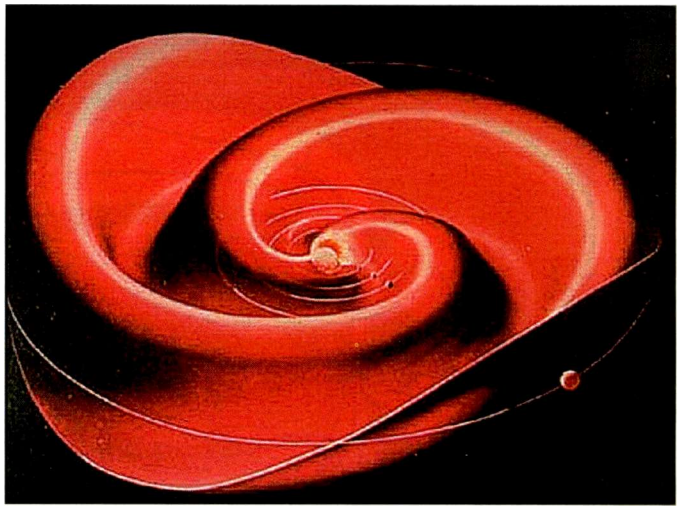
April is a hot month for DX. The seasonal change plays out on HF, with activity moving up from 41 meters and down from 11 meters. Propagation on the higher HF frequencies (19 through 11 meters) begins to suffer late in April and into the summer months due to lower MUFs in the Northern Hemisphere. MUFs peak very late in the day during the summer. Summertime MUFs are lower due to solar heating, which cause the ionosphere to expand. An expanded ionosphere produces lower ion density, which results in lower MUFs. Short-path propagation between countries in the Northern Hemisphere will drop out entirely. Higher frequency propagation peaks in the fall. April and May are fall months in the Southern Hemisphere, making long-path DX possible. Short-path propagation from South America, the South Pacific, and other areas south of the equator will be strong and reliable when open. However, these do not happen every day on the higher frequencies.

From April to June, excellent propagation occurs on both daytime and nighttime paths. The strongest propagation occurs on paths that span areas of both day and night, following the MUF. During April, peaking in May, and still in June, 16 meters may offer 24-hour DX to all parts of the world, with both short- and long-path openings occurring, sometimes at the same time! If you hear a lot of echo on a signal, you might be beaming in the wrong direction. Try the opposite azimuth. Thirty-one through 19 meters are more stable as nighttime bands, with propagation following gray-line and nighttime paths.

Low-band propagation is still hot on 41 meters, with Europe in the evenings and Asia in the mornings. Occasional DX openings will occur on 90 and 75 meters around sunrise.

Spring–The Season Of Aurora

Spring is also the season of aurora. Will we see a lot of aurora in April? As you might remember from past columns, each solar cycle tends to have *two* peak periods of geomagnetic activity in its 11-year cycle. The second peak is always a stronger, more intense period in which we witness frequent coronal holes, coronal mass ejections, and strong flare activity. We are well into the decline phase of solar Cycle 23 and may have finally passed the second geomagnetic activity peak of this cycle. However, I expect a moderate-to-high level of solar activity that may continue to keep the geomagnetic field at active to minor storm levels. This is because of the shedding of the Sun's complex magnetic structures, typical of a solar-cycle decline, combined with



Material from the Sun spirals away into the heliosphere in a complex current sheet. This spiral includes the IMF. (Source: NASA)

the current orientation of the Sun's magnetic poles, which were reversed, as explained earlier in this month's column.

If my prediction holds true, this possible geomagnetic storminess will fuel a fair amount of aurora. And for VHF weak-signal enthusiasts, this could be an active radio aurora season. However, this same increase in geomagnetic storminess will cause a general degradation of shortwave radio propagation, since such activity causes the ionosphere to lose energy. This weakens the ionosphere, causing the maximum usable frequencies to fall by as much as 30 percent on a given signal path (say, between Australia and the eastern United States).

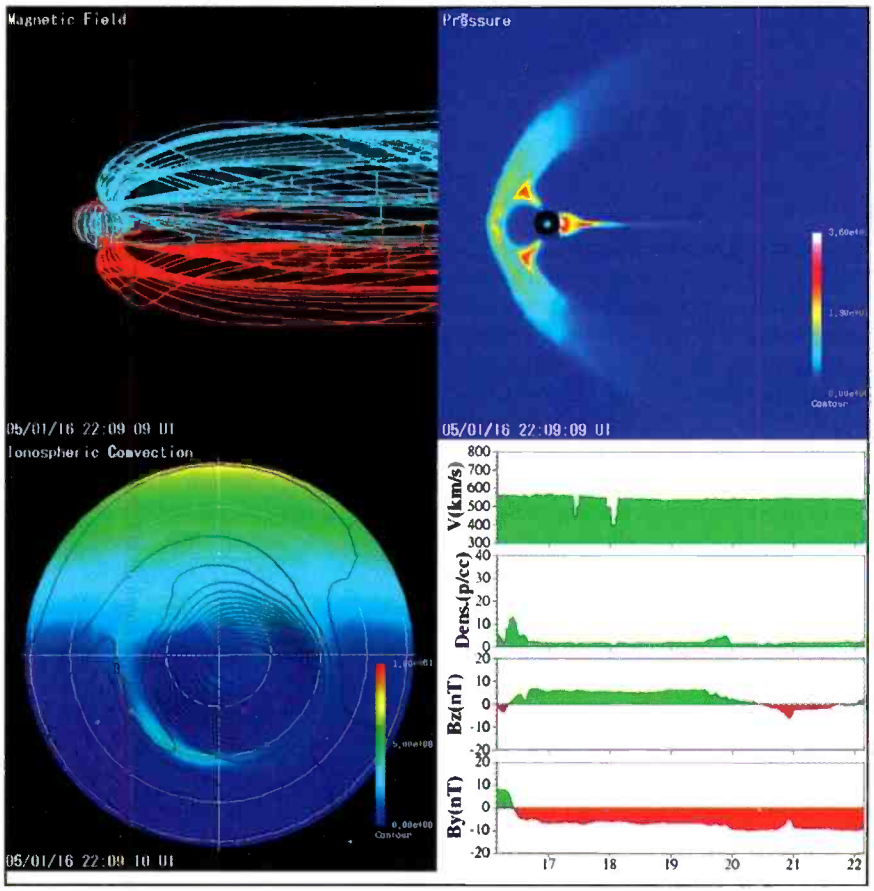
Geomagnetic storms that ignite auroras occur more often during the months around the equinoxes in early autumn and spring. This seasonal effect has been observed for more than 100 years. Scientists are still puzzled about all of the reasons, but they have a wealth of research from which they've developed models to help understand the phenomenon.

VHF Ionospheric Openings

On VHF, many different types of propagation modes can appear once or twice during April. Combination propagation modes may be possible on VHF, making for some exciting openings. Aurora is highly likely, as is an increase in trans-equatorial (TE) propagation. On days of high solar flux, there might be F2-mode VHF openings. Sporadic-E will become more common as we move into late spring and summer. There are times when sporadic-E, TE, and F2-layer propagation modes will link, providing strong DX openings on VHF between North America and New Zealand, Australia, or other areas.

If there are enough solar particles flowing down the Earth's magnetic-field lines and colliding with atmospheric atoms and molecules, ionization occurs. This ionization may be sufficient to reflect VHF and lower UHF radio waves, generally between 25 and 500 MHz. This usually occurs in conjunction with visual aurora, but the mechanism is a bit different and it is possible to have one (visual or radio) without the other.

Using radio aurora, the chances of contacting stations over greater distances than would ordinarily be possible on the VHF frequencies are increased. Like its visual counterpart, radio



These two images model the magnetosphere under a moderate solar wind speed (550 km/s) and a very fast solar wind speed (800+ km/s). The compression of the magnetosphere causes the ionosphere to recombine, causing the maximum usable frequency (MUF) on a given path to become depressed by as much as 30 percent. (Credit: Simulator Group, Applied Research and Standards, Division/Communications Research Laboratory/Koganei, Tokyo)

aurora is very unpredictable. The thrill of the chase draws many VHF weak-signal DXers to work auroral DX.

VHF auroral echoes, or reflections, are most effective when the angle of incidence of the signal from the transmitter, with the geomagnetic field line, equals the angle of reflection from the field line to the receiver. Radio aurora is observed almost exclusively in a sector centered on magnetic north. The strength of signals reflected from the aurora is dependent on the wavelength when equivalent power levels are employed. Six-meter reflections can be expected to be much stronger than 2-meter reflections for the same transmitter output power. The polarization of the reflected signals is nearly the same as that of the transmitted signal.

The K index is a good indicator of the expansion of the auroral oval, and the possible intensity of the aurora. When the K index is higher than 5, most readers in the northern states and in Canada can expect favorable aurora conditions. If the K index reaches 8 or 9, it is highly possible for radio aurora to be worked by stations as far south as California and Florida. Your magnetic latitude can be found using the map at http://www.sec.noaa.gov/Aurora/globeNW.html.

I have a wealth of links at http://prop.hfradio.org/ that provide up-to-the-minute aurora information and data. One of the most useful resources is http://aurora.n1bug.net/, the "Aurora Sentry." Also, check out *CQ VHF* magazine for details regarding VHF propagation through the spring and summer.

Propagation Questions? I'd Like To Hear From You

You can join in with others in discussing space weather, propagation, and shortwave or VHF listening at http://hfradio.org/forums/. Be sure to check out the latest conditions, as well as the educational resources for propagation, which I have put together for you at http://prop.hfradio.org/. I also provide a WAP/WML resource for wireless devices. If you want the latest propagation information, such the solar flux, Ap reading, and so forth, check out http://wap.hfradio.org/, the wireless version of my propagation site.

Please don't hesitate to write and let me know about any interesting propagation you have noticed. Do you have questions about propagation? I look forward to hearing from you at either P.O. Box 213 Brinnon, WA 98320-0213, or via e-mail at pc-prop-man@hfradio.org. Happy signal hunting! ■

Correction

In the February column, on page 18, the captions for the two figures were swapped. The figure on the top left of the page shows the Ap levels during the storm of November 7–10, 2004, while the bottom right figure shows the Kp levels during the same time period.

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by Tomas Hood, NW7US, pc-prop-man@hfradio.org

Reviewing Propagation And Space Weather Terms—Part IV The Ionosphere

Earth's atmosphere is a mixture of gases held to the surface of the Earth by gravity. These gases vary in density and composition as the altitude increases above the surface. As the atmosphere extends outward from Earth, it becomes thinner and blends with the particles of interplanetary space.

The first 60 miles of Earth's atmosphere consists of a homogeneous mixture of various gases. This region is called the *homosphere*. Above the homosphere, where gases are no longer uniformly mixed, lies the *heterosphere*. Relatively more of the heavy gas molecules, such as N_2 and O_2, are found near the bottom of the heterosphere, while relatively more of the lighter gases, such as hydrogen and helium, are found hear the top.

The atmosphere is also divided into four regions according to temperature trends: the *troposphere*, *stratosphere*, *mesosphere*, and the *thermosphere*. The lowest region is the troposphere and it extends from the Earth's surface up to about six miles. The gases in this region are heavier than those in higher altitudes, and include molecular oxygen (O_2) and molecular nitrogen (N_2). The highest mountains reach into this region and it is where the high-altitude jet stream flows. Weather is confined to this lower region and it contains 90 percent of the Earth's atmosphere and 99 percent of the water vapor.

The atmosphere above the troposphere is called the stratosphere and starts at about six miles out. Gas composition changes slightly as the altitude increases and the air thins. In this layer, incoming solar radiation at wavelengths below 240 nanometers creates ozone, a molecule of oxygen consisting of three oxygen atoms (O_3). This gas reaches a peak density of a few parts per million at an altitude of about 16 miles.

At an altitude above 50 miles, the gas is so thin that free electrons can exist for short periods before being captured by a nearby positive ion. The existence of charged particles at this alti-

The Ap Index And Understanding Propagation Terminology

The Ap index, or Planetary A index, is a 24-hour averaging of the Planetary K index. The Planetary K index is an averaging of worldwide readings of Earth's geomagnetic field. High indices (Kp > 5 or Ap > 20) mean stormy conditions with an active geomagnetic field. The more active, the more unstable propagation is, with possible periods of total propagation fade-out. Especially around the higher latitudes and especially at the Polar Regions, where the geomagnetic field is weak, propagation may disappear completely. Extreme high indices may result in aurora propagation, with strongly degraded long distance propagation at all latitudes. Low indices result in relatively good propagation, especially noticeable around the higher latitudes, when transpolar paths may open up. Maximum K-index is 9, and the A-index can exceed well over 100 during very severe storm conditions, with no maximum.

Classification of A-indices is as follows:

A0–A7 = quiet	A30–A49 = minor storm
A8–A15 = unsettled	A50–A99 = major storm
A16–A29 = active	A100–A400 = severe storm

Solar Flux (SFI): This flux number is obtained from the amount of radiation on the 10.7-cm band (2800 MHz). It is closely related to the amount of ultraviolet radiation, which is needed to create the ionosphere. Solar Flux readings are more descriptive of daily conditions than the Sunspot Number. The higher the Solar Flux (and, therefore, the higher the Sunspot Number), the stronger the ionosphere becomes, supporting refraction of higher frequencies.

Ionosphere: A collection of ionized particles and electrons in the uppermost portion of the Earth's atmosphere, which is formed by the interaction of the solar wind with the very thin air particles that have escaped Earth's gravity. These ions are responsible for the reflection or bending of radio waves occurring between certain critical frequencies, with these critical frequencies varying with the degree of ionization. As a result, radio waves having frequencies higher than the Lowest Usable Frequency (LUF) but lower than the Maximum Usable Frequency (MUF) are propagated over large distances.

Sunspot Number (SSN): Sunspots are magnetic regions on the Sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field. Sunspots appear as dark spots on the surface of the Sun. Temperatures in the dark centers of sunspots drop to about 3700° K (compared to 5700° K for the surrounding photosphere). This difference in temperatures makes the spots appear darker than elsewhere. Sunspots typically last for several days, although very large ones may last for several weeks. They are seen to rotate around the sun, since they are on the surface, and the sun rotates fully every 27.5 days.

Sunspots usually occur in a group, with two sets of spots. One set will have positive or north magnetic field while the other set will have negative or south magnetic field. The field is strongest in the darker parts of the sunspots (called the "umbra"). The field is weaker and more horizontal in the lighter part (the "penumbra").

Galileo made the first European observations of sunspots in 1610. The Chinese and many other early civilizations have records of sunspots. Daily observations were started at the Zurich Observatory in 1749; continuous observations were begun in 1849.

The sunspot number is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The "sunspot number" is then given by the sum of the number of individual sunspots and 10 times the number of groups. Since most sunspot groups have, on average, about 10 spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see. Monthly averages (updated monthly) of the sunspot numbers show that the number of sunspots visible on the sun waxes and wanes with an approximate 11-year cycle.

For more information, see http://prop.hfradio.org.

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tude and above marks the beginning of the *ionosphere*, a region having the properties of both gas and plasma.

Above the ionosphere exists the *magnetosphere*, a vast region of charged particles formed by the interaction between the solar wind and the Earth's magnetic field. The magnetosphere begins at about 600 miles above the Earth's surface. It extends to a distance of about 40,000 miles on the side facing the sun and to even greater distances on the far side of the Earth, away from the sun.

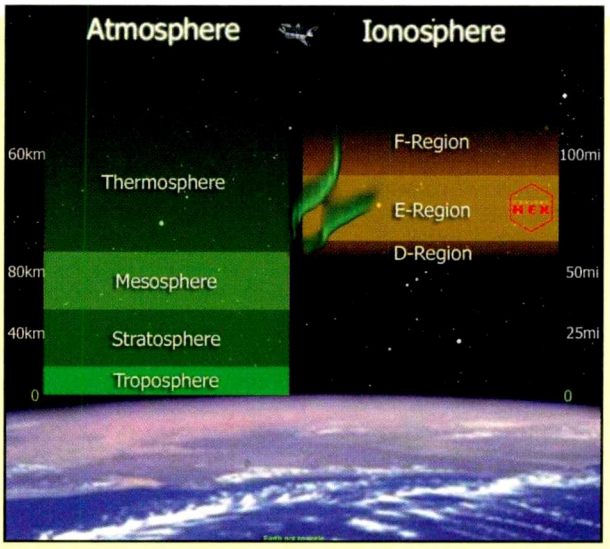
How Is The Ionosphere Formed?

Much of the energy from the sun that reaches our atmosphere is absorbed. Thankfully, nearly all the hazardous ultraviolet radiation, gamma rays, and x-rays are blocked before they reach Earth's surface. While most of the radiation from the sun is absorbed, some of it penetrates deeply into the atmosphere. Atmospheric ozone in the ozone layer is the greatest absorber of ultraviolet radiation, protecting virtually all life forms on Earth. Solar radiation at ultraviolet and shorter wavelengths is considered to be "ionizing" since photons of energy at these frequencies are capable of dislodging an electron from a neutral gas atom or molecule during a collision. We measure solar activity at the 10.7-centimeter frequency since it's close to the ultraviolet range and because the stronger the energy at that frequency, the more ionization occurs. This measurement is called the "solar flux reading."

Atoms in the ionosphere absorb the incoming solar radiation, causing them to become highly excited. When an atom is bombarded with enough of this energy, an electron may be knocked away from its orbit, producing free electrons and positively charged ions. At the highest levels of the Earth's outer atmosphere, solar radiation is very strong but there are few atoms to interact with, so ionization is low. As the altitude decreases, more gas atoms are present, so the ionization process increases. At the same time, however, an opposing process begins to occur. In this process, called *recombination*, a free electron is "captured" by a positive ion if they get too close to each other. As the gas density increases at lower altitudes, the recombination process accelerates since the gas molecules and ions are closer together.

Because the composition of the atmosphere changes with altitude, the ion production rate also changes, leading to the formation of several distinct ionization regions, known as the *D*, *E*, F_1, F_2, and F_3 layers. (Yes, an outer F_3 layer has been discovered, and so far it seems that when present, it is most dense over the equatorial region during the peak of day). The breakdown between layers is based on the density of ions and what wavelength of solar radiation is absorbed most frequently in that region.

The *D* region is the lowest in altitude and absorbs the most energetic radiation, known as hard x-rays. The *D* region doesn't have a definite starting and stopping point, but includes the ionization that occurs below about 56 miles. This region absorbs high frequency (HF) waves between 3 and 30 MHz or wavelengths between 100 meters and 10 meters. It refracts frequencies in the range of 3 to 30 kHz, or very low frequencies (VLF). The *D* region is a daytime layer because it takes the full energy of the sun to keep the very dense layer of gases ionized. Once sunlight is removed, the free electrons quickly recombine with the gases and molecules that are so densely packed, and the ionization nearly disappears.



The layers of Earth's atmosphere. Note that aurora occurs mostly at the height of the E *region, which is why propagation of radiowaves off the ionized clouds formed during active aurora acts somewhat like sporadic-*E. *(Source: HEX)*

The next highest layer, the *E* region of the ionosphere, extends from about 56 miles to about 65 miles. The air in this region is considerably thinner than below it. Because of the thinness this air, there are fewer collisions of ions and electrons, resulting in a population of molecular ions. The *E* region absorbs soft x-rays. This layer is highly variable from day to night, and takes longer to recombine than the *D* layer.

The highest layer is the *F* region, which is the largest part of the ionosphere. It extends from about 65 miles up through the end of our atmosphere. Since particle densities decrease as you travel away from Earth, it is difficult to say exactly where our atmosphere ends. Since it is such a large region, the *F* layer is divided into two main sections: the daytime layer, F_1, and the denser F_2 region, which exists both during the day and night. A third layer has been discovered, the F_3 region, which appears to occur during the peak solar cycle years over the equatorial region during the middle of the day.

In the *F* region, gravity's affect on particles creates different layers, depending on their mass. The heavier particles sink to the bottom of the *F* region and the lighter ones rise to the top. Along the day/night meridian electron numbers rise and fall. At sunset, electron numbers decrease and recombination of these particles with ions occurs throughout the night. On the sunrise meridian, electron numbers increase as neutral molecules and atoms are energized by solar radiation, again causing ionization.

Radio Waves In The Ionosphere

As an electromagnetic wave enters the ionosphere at the *D* layer, the energy sets electrons in a vibrating motion (at the frequency of the radiowave). Because this layer is so dense, there's a high probability that the energy will be absorbed in a collision with nearby molecules. The electromagnetic energy is turned into kinetic energy (heat) and, as far as radio propagation is concerned, lost. The higher the frequency and the short-

Optimum Working Frequencies (MHz) - For May 2005 - Flux = 81, SSN = 22- Created by NW7US

UTC TO/FROM US WEST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	22	22	22	21	19	18	16	15	14	13	12	11	12	14	16	17	18	19	20	21	21	22	22	22
NORTHERN SOUTH AMERICA	29	28	28	26	23	21	20	18	17	16	15	14	14	17	19	22	23	25	26	27	28	28	28	29
CENTRAL SOUTH AMERICA	28	25	23	21	19	18	17	16	15	14	14	16	16	18	21	23	25	26	27	28	29	30	30	29
SOUTHERN SOUTH AMERICA	24	18	16	16	15	14	13	13	13	12	12	12	12	15	18	20	22	24	26	27	28	28	28	26
WESTERN EUROPE	12	11	10	10	9	11	13	12	11	11	10	14	16	17	18	19	20	20	20	19	19	18	17	15
EASTERN EUROPE	9	9	9	9	13	15	13	11	11	10	10	10	14	16	18	19	19	19	18	17	16	14	10	10
EASTERN NORTH AMERICA	26	25	25	24	23	22	20	18	17	16	14	14	16	18	20	21	23	24	24	25	25	26	26	26
CENTRAL NORTH AMERICA	14	14	14	14	13	13	12	11	10	9	9	8	8	9	11	11	12	13	13	14	14	14	14	14
WESTERN NORTH AMERICA	8	8	7	7	7	7	7	6	6	5	5	4	4	4	5	6	6	6	7	7	7	7	7	8
SOUTHERN NORTH AMERICA	23	23	23	23	22	21	19	18	16	15	14	13	12	13	16	17	19	20	21	22	22	23	23	23
NORTHERN AFRICA	16	15	13	12	12	12	14	13	12	11	12	15	17	18	19	19	20	20	21	21	20	20	19	17
CENTRAL AFRICA	17	16	15	14	13	14	13	12	11	11	10	14	16	18	19	19	20	20	21	21	21	21	21	19
SOUTH AFRICA	16	15	14	14	13	13	15	17	16	15	14	16	18	20	21	22	23	24	24	23	21	19	18	17
MIDDLE EAST	13	12	12	13	15	15	12	12	11	10	10	12	15	17	18	19	20	20	20	19	18	17	16	14
JAPAN	20	20	21	20	20	20	19	18	18	16	15	14	13	13	14	14	13	12	12	14	16	17	18	19
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CHINA	19	20	20	20	20	19	18	17	16	14	13	12	11	12	15	16	15	13	12	12	14	16	17	18
SOUTH PACIFIC	29	30	30	29	28	26	24	18	16	15	15	14	13	13	13	12	12	12	12	21	25	27	28	29

UTC TO/FROM US MIDWEST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	25	25	24	24	21	20	18	16	15	14	13	13	14	17	18	20	21	22	23	24	24	25	25	25
NORTHERN SOUTH AMERICA	26	26	25	23	21	19	18	16	15	14	14	13	14	16	18	20	22	23	24	25	25	26	26	26
CENTRAL SOUTH AMERICA	28	25	23	21	19	18	17	16	15	14	14	15	17	20	22	24	25	26	27	28	29	29	29	29
SOUTHERN SOUTH AMERICA	23	18	17	16	15	14	14	13	13	12	12	12	15	18	20	22	24	25	26	27	28	29	28	26
WESTERN EUROPE	15	13	12	11	10	11	13	12	12	14	16	17	18	18	19	19	20	20	20	20	19	19	18	17
EASTERN EUROPE	10	9	9	9	9	13	12	12	11	11	14	16	18	19	19	20	20	19	19	18	17	16	14	10
EASTERN NORTH AMERICA	18	18	18	17	16	15	14	13	12	11	10	10	12	13	15	16	16	17	18	18	18	18	19	19
CENTRAL NORTH AMERICA	9	8	8	8	8	7	7	6	6	5	5	4	5	6	6	7	7	8	8	8	8	8	9	9
WESTERN NORTH AMERICA	15	14	14	14	14	13	12	11	10	9	9	8	8	9	10	11	12	13	13	14	14	14	14	15
SOUTHERN NORTH AMERICA	16	16	16	16	15	14	13	12	11	10	9	9	9	10	11	13	13	14	15	15	16	16	16	16
NORTHERN AFRICA	20	18	17	16	14	14	14	13	12	13	15	16	18	19	19	20	20	21	21	21	21	21	21	21
CENTRAL AFRICA	17	16	15	14	13	13	14	13	12	13	15	17	18	19	19	20	20	21	21	21	21	21	21	19
SOUTH AFRICA	15	15	14	13	13	13	13	19	18	17	16	18	21	23	25	26	28	28	26	22	20	19	17	16
MIDDLE EAST	14	13	12	12	14	15	13	12	12	14	16	17	18	19	19	20	20	20	20	20	19	18	16	15
JAPAN	20	20	20	19	19	18	18	17	15	14	13	13	15	16	15	14	13	12	12	15	16	18	19	19
CENTRAL ASIA	20	20	20	19	19	18	17	16	14	13	12	12	15	16	17	18	18	16	15	14	14	15	17	19
INDIA	12	14	16	16	16	15	12	12	11	10	10	14	16	17	16	15	14	12	10	9	9	9	8	8
THAILAND	17	19	20	19	18	17	16	14	13	12	11	12	15	16	18	19	19	18	16	15	14	13	13	15
AUSTRALIA	29	30	30	30	30	29	28	25	23	21	19	18	17	16	16	15	14	14	13	13	17	23	26	28
CHINA	19	20	20	19	18	17	16	14	13	12	11	12	15	17	18	16	15	14	13	13	14	16	17	18
SOUTH PACIFIC	30	30	29	28	27	25	22	16	15	14	14	13	13	12	12	12	12	12	13	23	26	27	29	29

UTC TO/FROM US EAST COAST	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CARIBBEAN	20	20	19	18	16	15	14	13	12	11	10	10	12	14	15	16	17	18	19	19	20	20	20	20
NORTHERN SOUTH AMERICA	23	23	22	20	18	17	15	14	13	12	12	11	13	15	17	19	20	21	22	22	23	23	23	23
CENTRAL SOUTH AMERICA	27	25	22	21	19	18	16	15	15	14	14	16	19	21	23	24	25	26	27	28	28	29	29	29
SOUTHERN SOUTH AMERICA	21	18	17	16	15	14	14	13	13	12	12	12	17	20	22	23	25	26	27	28	28	29	27	25
WESTERN EUROPE	16	15	14	13	12	13	12	11	11	13	15	16	17	18	19	19	19	19	19	19	18	18	18	17
EASTERN EUROPE	11	10	10	9	9	14	13	12	13	15	17	18	19	19	20	20	20	20	19	19	18	17	15	12
EASTERN NORTH AMERICA	9	9	8	8	7	7	6	6	5	5	5	5	6	7	7	8	8	8	8	9	9	9	9	9
CENTRAL NORTH AMERICA	19	19	19	18	17	16	14	13	12	11	11	11	13	14	15	16	17	18	19	19	19	20	20	20
WESTERN NORTH AMERICA	26	26	25	24	24	22	20	18	17	16	15	14	16	18	20	21	23	24	24	25	25	26	26	26
SOUTHERN NORTH AMERICA	20	20	20	19	18	16	15	14	12	12	11	11	12	14	15	16	17	18	19	19	20	20	20	20
NORTHERN AFRICA	20	18	17	16	15	14	14	15	14	15	18	20	21	22	23	24	25	25	26	25	25	25	24	22
CENTRAL AFRICA	17	16	15	14	13	13	15	15	14	15	18	20	21	22	23	24	25	25	25	25	24	23	21	19
SOUTH AFRICA	15	15	14	13	13	13	13	17	16	15	17	19	21	23	25	26	27	28	26	22	20	19	17	16
MIDDLE EAST	17	16	15	14	14	14	13	12	12	14	16	17	18	19	20	20	21	21	21	21	21	21	21	19
JAPAN	20	20	19	19	18	17	15	14	13	13	14	16	17	16	15	14	13	12	13	15	17	18	19	19
CENTRAL ASIA	19	19	18	18	17	16	15	13	13	14	16	17	17	18	19	19	18	17	16	15	14	14	17	19
INDIA	9	9	9	9	14	14	13	13	13	15	17	18	18	19	19	19	18	18	17	16	14	11	10	9
THAILAND	16	18	18	17	16	14	13	12	12	15	16	17	18	19	19	20	20	19	17	16	15	14	13	14
AUSTRALIA	30	30	30	29	28	26	23	21	20	18	17	16	16	16	15	14	14	13	13	13	18	23	26	28
CHINA	18	19	18	18	17	15	14	13	12	14	16	17	18	18	18	17	16	14	14	14	15	16	17	18
SOUTH PACIFIC	29	29	29	28	26	24	20	15	15	14	13	13	13	12	12	12	12	12	17	23	26	27	28	29

er the wavelength, the higher the energy, but also the fewer collisions between free electrons and gas molecules than at lower frequencies. As a result, lower frequency signals are attenuated far more than are those at higher frequencies. It is possible that the lowest frequencies are completely absorbed, while higher frequencies will make it through to the *E* layer.

Since the *E* layer is less dense than the *D* layer, electrons are not so quickly recombined with neighboring atoms, so losses are lower. Because these electrons are not as quickly bound with other atoms, losing energy, the electromagnetic wave is re-radiated. Because the signal is traveling in an area where electron density is increasing, the farther it will go.

At the same time, the wave is bent away from the denser, and higher, area of electrons. The amount of bending, or *refraction*, is dependent on the frequency of the wave and the density of the ionosphere the radio wave is traveling through. Think of how a pencil might look if you place it into a glass of water. When you view the pencil through the side of the glass, it appears to bend right at the boundary between the air and the water. This is caused by the same phenomenon. Light is being refracted by the difference in density of the mass it is traveling through.

The higher the frequency, the more energy that wave has, making it more likely to pass through to the next higher region. When an electromagnetic wave enters the *F* layer, the same thing takes place. The radio signal rides the free electrons of this layer, and if the frequency of the signal is high enough, it will pass through the layer out into space; otherwise, it will be gradually refracted back, away from the higher and denser layers of electrons, to be sent back toward Earth.

Those frequencies that are refracted back to Earth have to then pass again through the lower ionospheric layers. *D*-layer absorption will attenuate the signal some more. If there is enough energy in the signal, the wave may bounce between the Ionosphere and Earth multiple times, greatly extending the distance it can travel. Other times, it might be absorbed to such a degree that no communications are possible. Yet at other times, a radiowave will enter the ionosphere, bounce off the *F* layer, but then refract back up away from the *E* layer, doing so over multiple hops until it can punch back through the *E* layer and back to Earth.

All this depends on how ionized the gases become in these various layers, and how dense each layer is, as well as on the strength, angle of incidence, and frequency of the radio signal. Ionization depends on direct energy from solar radiation. Would all of the layers of the ionosphere perform identically if they each received the same amount of solar energy? No, because of the different gases found in each layer and the density of those layers.

When we look at the daily measurements of the 10.7-centimeter solar flux, we find that the higher the index, the more ionized these various layers become, making it possible for higher shortwave frequencies to propagate by refraction over great distances. When the flux is low, the ionosphere is weaker and only the lower shortwave frequencies will be propagated. Of course, there are many variations during the day, between regions in daylight and darkness and from season to season.

Current Cycle 23 Progress

The Dominion Radio Astrophysical Observatory at Penticton, BC, Canada, reports a 10.7-centimeter observed monthly mean solar flux of 102.4 for January 2005, up from 94.6 for December 2004. The 12-month smoothed 10.7-centimeter

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flux centered on July 2004 is 105.9, just down from June's 107.2. The predicted smoothed 10.7-centimeter solar flux for May 2005 is about 81, give or take about 19 points.

The Royal Observatory of Belgium reports that the monthly mean observed sunspot number for January 2005 is 31.3, a nice jump up from December's 17.9, yet still down from November's 43.7. The lowest daily sunspot value during December, recorded on January 8, was 10. The highest daily sunspot count was 65 on January 16. The 12-month running smoothed sunspot number centered on July is 40.2, down from June's 41.7 (adjusted). A smoothed sunspot count of 26 to 32 is expected for May 2005 by the SIDC (Solar Influences Data analysis Center). The Space Environment Center predicts the sunspot count to be 18, give or take about 12 points.

The observed monthly mean planetary A-Index (Ap) for January 2005 is 22, quite a jump from December's 11. The 12-month smoothed Ap index centered on July 2004 is 13.8, about the same as for June. Expect the overall geomagnetic activity to be quiet to active during most days in May, with some isolated periods of storm level activity.

HF Propagation

As we move away from the winter shortwave season into the longer days of summer, the overall trend in shortwave propagation is the opening up of the higher frequencies into many areas of the world. However, these openings can be variable in strength, subject to fading, and could be short-lived. The cause of this change is complex. The length of daylight over a region of the ionosphere, the intensity of the solar radiation, and the density and height of the various layers of the ionosphere all affect the propagation of the shortwave frequencies we're interested in. Winter daytime propagation over a given path could sustain higher frequencies than the same path can during the summer daytime, while the summer nighttime frequencies will be higher than the winter nighttime frequencies on that same path.

On the higher HF frequencies (16 through 11 meters), fairly good daytime openings should be possible on north/south paths during May. Sixteen meters will be the best bet out of the higher bands, not only because of propagation, but also because more international broadcasters will still use this band around the clock.

Most DX signals, and the strongest signals, will be found on the middle and lower HF bands. When the 10.7-centimeter flux is high, especially above 100, conditions on 19 (and sometimes on 16) meters are great. However, since we're getting close to the end of the current solar cycle, the flux won't get above 100 very often. Instead, most signals will be found on the 15-MHz band or below.

Look for peaks in signals around the hours of sunrise, and again just before sunset, and into the late evening. Daytime paths are best when they terminate in areas where it is night. This enhances propagation to remote parts of the world and lengthens the DX window. Twenty-five and 22 meters will have more stable signals than those on 19 meters, especially on north/south paths, again around the hours of sunrise and sunset. Thirty-one meters again becomes one of the strongest and most reliable bands, though you will find it congested. Look for Europe and Africa early in the morning through late morning, then north/south openings during the day if the solar activity is low (otherwise the *D*-layer absorption will wipe out the band). As sunset approaches, look for the South Pacific, then Asia as the sun sets.

During the night, 41 through 60 meters should provide good openings from Europe, Africa, and the East. Some DX should be possible on 75 through 120 meters, but signals are expected to be mainly weak and covered by seasonal noise. Static levels also increase noticeably during May, and signals may sound weaker on DX openings during the daylight hours.

VHF Ionospheric Openings

Possible transequatorial (TE) propagation and occasional sporadic-*E* (*Es*) propagation will keep the VHF enthusiast happy. *Es* ionization is expected to increase considerably during May, and fairly frequent VHF meteor-scatter short-skip openings should be possible. These are likely to occur over distances of approximately 1,000 to 1,400 miles. Although *Es* openings can take place at just about any time, the best time to check is between 10 a.m. and 2 p.m. and again between 6 p.m. and 10 p.m. local daylight time.

A seasonal decline in TE propagation is expected during May. An occasional opening may still be possible on VHF, however. The best time to check for VHF TE openings is between 9 and 11 p.m. local daylight time. These TE openings will be north/south paths that cross the geomagnetic equator at an approximate right angle.

Auroral activity is generally lower than March and April, due to the change in the orientation and position of the Earth and magnetosphere in relation to the solar wind. Watch for Kp values above 6, which occur on days when we see coronal holes affecting space weather or the arrival of coronal mass ejections a few days after any major solar flare.

One meteor shower, the **Eta Aquarids**, will occur in May. The Eta Aquarids peak at **2400 UTC, May 5**, but start around April 19, 2005. This shower has a peak rate of up to 60 visuals per hour. This year, the shower will be best viewed from the tropics or in the Southern Hemisphere. The current thinking is that the next big occurrence of this shower will be sometime between 2008 and 2010, with enough of an increase in activity to make an exciting event in the Northern Hemisphere. Nevertheless, if you're in the Northern Hemisphere, look for TV and FM broadcast pings (short bursts of signals, refracted off the ionized trails from the burning meteorite) during these events. If you're an amateur radio operator, look for 6- and 2-meter openings off the ionized meteor trails.

I'd Like To Hear From You

You can join in with others in discussing space weather, propagation, and shortwave or VHF listening at http://hfradio.org/forums/. Be sure to check out the latest conditions, as well as the educational resources about propagation, that I've put together for you at http://prop.hfradio.org/. I also provide a WAP/WML resource for wireless devices. If you want the latest propagation information like the solar flux, Ap reading, and so forth, check out http://wap.hfradio.org/, the wireless version of my propagation site.

Please don't hesitate to write and let me know about any interesting propagation you've noticed. Do you have any questions about propagation? Send them in, too. I look forward to hearing from you. Happy signal hunting! ■